Volume 21 Number 3

COMMONWEALTH OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC

AND

INDUSTRIAL RESEARCH

AUGUST 1948

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314 *Albert Street,*
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J. J. GOURLEY, Government Printer, Melbourne.

C.7375/48.

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The Insecticidal Control of Cabbage Pests : A Summary of Experimental Results, 1944-48

By T. Greaves and D. G. Venables**

1. Introduction

Investigations on the control of cabbage pests by insecticides were begun by the Division of Economic Entomology as a war-time project, and early results of this work were reported by Greaves (1945)†. More extensive tests of DDT and benzene hexachloride (BHC), as well as insecticides such as hexaethyltetraphosphate (HETP), which became available subsequently, were carried out in the Canberra district from 1944-48. The detailed results of these investigations are being prepared for publication and the present summary is intended as a guide for insecticide manufacturers and commercial market gardeners in the coming season.

Before DDT was used as an insecticide on cabbages, growers in the Canberra district were able to market only two crops each season: a spring crop and a winter crop. The intention was to harvest the spring crop before the pest populations had assumed serious proportions, for lead arsenate could not be applied to hearting cabbages, and rotenone dusts resulted in poor control. The problem of securing a good winter crop was one of preventing the destruction of the seedlings until low temperatures reduced pest activity. However, weekly applications of 0·5 per cent. lead arsenate plus 0·05 per cent. nicotine spray still resulted in an average loss of 30 per cent. of the marketable heads.

Intensive tests with DDT were prompted by successful preliminary results obtained with this insecticide in North Queensland against severe infestations of cabbage moth (*Plutella maculipennis* Curtis) and green peach aphid (*Myzus persicae* Sulz.); they were further stimulated when DDT became more freely available at reduced prices as the investigations proceeded, thus making it possible to increase the concentration of the insecticide without making the cost of materials prohibitive.

* An officer of the Division of Economic Entomology.

† Greaves, T. (1945).—Experiments on the control of cabbage pests in North Queensland. *J. Coun. Sci. Ind. Res.* (Aust.) 18: 110-20.

Table 1.—Selected Results

	1944–45			1945–46				1946–47			1947–4			
	Moth		Aphid	Moth		Aphid		Moth		Aphid	Aphid	Aphid		Aphid
	Mean Rating	$\log \frac{x}{4-x}$*	Mean Rating	Mean Rating	$\sqrt{100x}$*	Mean Rating	$\sqrt{100x}$*	Mean Rating	$\sqrt{\ }$*	Mean Rating	Mean Rating	Mean Rating	log $100x$*	Co-variance*
Treatment—Dusts														
†DDT 0·5 per cent. in pyrophyllite ..	0·75	0·76	1·11	..	..	..	..	0·72	0·83	2·34	..	..	..	..
DDT 1 per cent. in pyrophyllite ..	0·50	0·65	1·25	0·17	3·98	0·51	7·12	0·19	0·42	2·61	..	..	..	..
‡BHC 0·125 per cent. in pyrophyllite ..	2·73	1·87	0·51	..	..	..	..	1·54	1·24	1·16	..	..	..	..
BHC 0·25 per cent. in pyrophyllite ..	1·64	1·33	0·54	0·37	5·84	0·07	2·30	1·54	1·21	0·99	..	..	..	..
HETP 2·5 per cent. v/w in pyrophyllite	..	..	..	..	..	..	..	..	..	..	..	..	..	2·21
HETP 5 per cent. v/w in pyrophyllite ..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·79
DDT 0·5 per cent. + BHC 0·125 per cent. in pyrophyllite	..	..	..	..	..	..	..	0·44	0·65	1·32	0·37	..	..	..
DDT 1 per cent. + HETP 5 per cent. v/w in pyrophyllite	..	..	..	..	..	..	..	..	..	..	0·70	..	..	..
DDT 1 per cent. + rotenone 1 per cent. in pyrophyllite	..	..	..	0·28	4·64	0·33	5·38	0·39	0·60	1·98	..	..	..	..

TREATMENT—DUSTS—*continued*														
DDT 1 per cent. + nicotine 2·4 per cent. w/w (≡ "Black Leaf 40" 5 per cent. v/w) in hydrated lime	..	..	..	1·65	12·78	0·09	2·78	2·34	1·52	0·38	..	..	..	..
DDT 1 per cent. + nicotine 2·4 per cent. w/w (≡ "Black Leaf 40" 5 per cent. v/w) in pyrophyllite	..	..	..	0·21	4·14	0·17	3·94	0·28	0·52	0·70	0·52	..	..	..
Sodium aluminium fluoride (synthetic cryolite) 40 per cent. in pyrophyllite ..	3·15	2·35	1·01	2·10	14·14	0·86	9·14	..	..	..	..	..	..	..
Lead arsenate 20 per cent. + nicotine 2·4 per cent. w/w (≡ "Black Leaf 40" 5 per cent. v/w) in pyrophyllite ..	2·78	1·86	0·33	1·87	13·36	0·14	3·44	2·36	1·51	1·65	..	..	..	..
TREATMENT—SPRAYS														
DDT 0·05 per cent. emulsion	0·44	0·58	1·21	..	..	..	..	0·24	0·47	1·96	..	..	..	..
DDT 0·1 per cent. emulsion	0·14	0·04	0·89	0·10	2·68	0·13	3·46	0·04	0·17	1·08	..	..	..	..
BHC 0·0125 per cent. emulsion ..	0·70	0·80	0·35	0·33	5·70	0·03	1·00	1·46	1·18	0·79	..	..	..	..
BHC 0·025 per cent. emulsion ..	0·39	0·46	0·20	0·09	2·88	0·03	1·62	0·72	0·84	0·44	..	..	..	..
HETP 0·0625 per cent.	..	..	..	..	..	..	..	..	..	..	..	..	..	1·26
HETP 0·125 per cent.	..	..	..	..	..	..	..	..	..	..	..	..	..	0·84

* Transformed mean rating. † All DDT concentrations are given on the basis of the para-para isomer.
‡ All BHC concentrations are given on the basis of the gamma isomer.

(*c*) No single insecticide effectively controlled both cabbage moth and cabbage aphid. To obtain reasonable control of aphids, the concentration of DDT has to be increased to at least four times that required for moth control. Solvent naphtha—"Wetsit" emulsions of DDT control aphids to some extent, but not sufficiently to warrant the omission of a specific aphicide.

(*d*) The most effective dust was one containing 1 per cent. DDT plus 2·4 per cent. w/w nicotine* in an inert diluent, and applied at fortnightly intervals. A dust containing 0·5 per cent. DDT plus 0·125 per cent. gamma isomer BHC was also effective; but one containing 1 per cent. DDT plus 5 per cent. v/w HETP, freshly mixed, was much less effective against the aphid.

(*e*) The most effective spray contained 0·1 per cent. DDT plus 0·125 per cent. HETP, freshly mixed; a spray containing 0·1 per cent. DDT plus 1 per cent. w/v soft soap also proved effective at both low and high temperatures. Other effective sprays were 0·05 per cent. DDT plus 0·0125 per cent. gamma isomer BHC, and 0·1 per cent. DDT plus 0·05 per cent. nicotine†.

(*f*) DDT—nicotine sulphate dusts in which hydrated lime or other alkaline materials were used as diluent, failed to control cabbage moth; such alkalis react with DDT, greatly impairing the insecticidal qualities of the dust.

(*g*) The newer aphicides, HETP and BHC, were not as effective in hot weather against the cabbage aphid as dusts containing 2·4 per cent. w/w. nicotine.

(*h*) When compared with DDT and the more efficient aphicides, insecticides such as lead arsenate, rotenone, pyrethrins, cryolite, white oil, "Ryanex", and dithiocyanodiethyl ether gave poor control.

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*2·4 per cent. w/w nicotine = 1 pint of "Black Leaf 40" to 20 lb. of dust.

†0·05 per cent. nicotine = 1 pint of "Black Leaf 40" to 100 gallons.

Some Modifications of the McMaster Helminth Egg-Counting Technique and Apparatus

*By H. V. Whitlock**

Summary

Modifications of the McMaster helminth egg-counting technique and apparatus are described and the advantages enumerated. A new cement for glassware is also described.

1. Introduction

The original method (Gordon and Whitlock 1939) of counting helminth eggs has undergone a number of modifications during the past years. In making the modifications the aim has been to increase the speed and preserve the simplicity while maintaining accuracy.

Considerable variation in susceptibility and reaction to helminth infestation from sheep to sheep necessitated the use of relatively large numbers of animals, particularly in field trials. Accordingly it has become necessary to carry out increasingly larger numbers of egg counts on fæcal samples.

2. Modifications in Techniques and Apparatus

(*a*) *Preparation of the Fœcal Suspension*

The original technique has been altered only by the method of stirring the suspension. A sample of 2 g. is weighed out from the fæcal specimen, placed in a square "pomade" jar (2 fl. oz. capacity) and 20 ml. water is added. This mixture is allowed to stand for one or two hours, or occasionally overnight, in a refrigerator, in order to ensure thorough breaking down of the fæcal material. On some occasions a saturated watery solution of ortho-dichloro-benzene is used in the preliminary soaking of the fæcal sample. Ortho-dichloro-benzene poisons the eggs, thereby preventing further development of the embryo, and since it does not impair floatability of the eggs it may be used for the dual purpose of soaking the fæcal material and preventing development of the eggs. It is particularly useful where a refrigerator is not available. In field work during hot weather it is the usual practice to weigh out the 2-g. samples soon after collection from the sheep and place them in jars with 10-20 ml. saturated watery solution of ortho-dichloro-benezene until the samples are taken to the laboratory for counting, possibly 24 hours later. The use of ortho-dichloro-benzene for this purpose has been discussed by Whitlock (1943).

When the fæcal sample has been thoroughly soaked in water, or in watery solution of ortho-dichloro-benzene, the suspension is made up to a volume of 60 ml. with saturated sodium chloride solution. The suspension is then thoroughly stirred by means of the electric mixer described by Kauzal and Gordon (1941).

* An Officer of the McMaster Animal Health Laboratory, Sydney, Division of Animal Health and Production.

(*b*) *Removal of a Sample from the Suspension*

A new type of sieve pipette is employed. It is attached to a piece of rubber tubing about 48 cm. in length, fitted with a glass mouthpiece. The sieve pipette consists of a glass tube 10 cm. long with an internal diameter of 8 mm. On the lower end a piece of rubber tubing is fitted which overlaps the end of the glass tube by 4 mm. On the inside of this overlapping piece of rubber tubing a circular groove is cut, into which is fitted a circular piece of metal gauze (12 meshes per cm.). By allowing the fæcal suspension to run in and out through this gauze large pieces of fæcal debris are excluded from the sample which is finally placed in the counting chamber. The gentle flow of fæcal suspension through the gauze is assisted by sucking and blowing through the rubber tubing attached to the pipette. It is emphasized that the flow of fæcal suspension through the gauze must be gentle and not forced, otherwise blockage by debris may occur.

(*c*) *The Counting Chamber*

The original counting-chamber slide (Gordon and Whitlock 1939) consisted of glass pieces cemented together with Canada Balsam. It had a glass base 7·5 cm. by 2·6 cm. to which were cemented four glass strips each 1·5 mm. thick by 4 mm. wide. A top piece 7·5 cm. by 1·5 cm. with three squares 1 cm. by 1 cm. engraved on the under

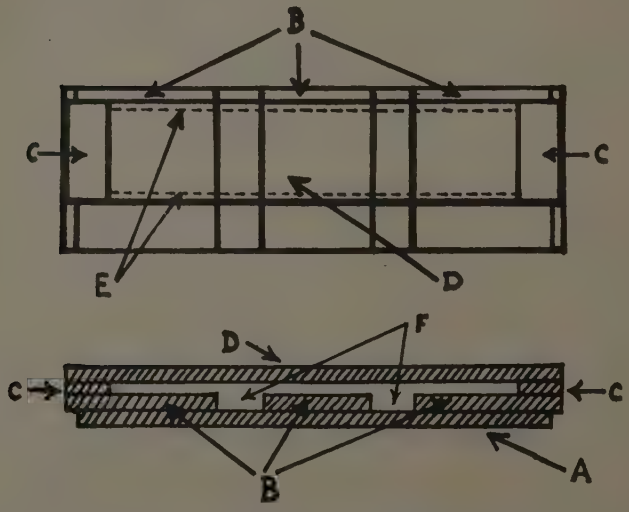

FIG. 1.—A, base; B, platforms; C, supporting strips; D, top piece; E, ruled lines; F, troughs.

surface was cemented on top of the cross pieces. The top piece was set off-centre so that a wider platform was provided on one side to facilitate filling of the counting chambers.

The new counting-chamber slide (Fig. 1) has a base (A) 7·5 cm. by 2·6 cm. At either end and in the centre are glass platforms (B) 3 mm. in thickness. The two end platforms measure 2·4 cm. by 2·6 cm. and the centre platform measures 1·7 cm. by 2·6 cm. Two troughs (F) are thereby provided. The end platforms overlap the base by 2 mm. On the end platforms are mounted supporting strips (C) 1·5 mm. thick and 7 mm. by 1·5 cm. The top piece (D) measures 7·9 cm. by 1·5 cm. and on its under surface are ruled parallel lines (E) 1·5 cm. apart.

(d) The Glassware Cement

The new counting-chamber slide is, like the original one, made of glass pieces, but the cement now used is a new preparation which is almost shatter-proof, does not become brittle with age and withstands washing in hot water. This cement is made as follows:

Boil carefully together 80 g. best quality synthetic ("Button") shellac and 100 ml. ortho-dichloro-benzene; add 20 g. lump Canada balsam and allow to cool to a jelly; roll into sticks and wrap in cellophane.

When making the counting chambers apply the cement to heated glass and press the pieces together. Do not heat the cement jelly in a flame. The apparatus may be used immediately after cooling, but it should not be washed in hot water until the cement has been allowed to set for about seven days.

(e) Counting the Eggs

A sample of the fæcal suspension prepared, mixed and withdrawn with a sieve pipette as described above, is run into the space between the platform (B) and the top piece (D). (See Fig. 1.) The troughs (F) prevent the suspensions from adjoining platforms mixing. The eggs soon rise in the sodium chloride solution and come to rest against the under surface of the top piece (D). Debris sinks onto the platforms where it is out of focus when the eggs are counted.

The combination of objectives and oculars employed is usually a 1a and 10x, respectively. The draw tube of the microscope, or the mask in the ocular is then adjusted to give a field with a diameter of 4 mm. when the eggs are in focus. If two traverses are then made between the lines ruled on the under surface of the top piece (D) the eggs in a volume of 0·15 ml. can be counted. This volume is calculated from the dimensions of the space occupied by fæcal suspension, viz., 1·5 by 12·5 by 8 mm. = 0·15 ml. or 1/400 of the original 60 ml. fæcal suspension which contains 2 g. fæces, giving a factor of X200 to convert the number of eggs counted to number of eggs per gram of the original fæcal sample. If additional traverses are made the factor is merely reduced accordingly. The width of the platform (B), 17 mm., provides for four traverses. If a 2 mm. field is used a combination of a 2/3 objective and 10x ocular is used.

3. Advantages of the Modified Method

(*a*) Counting time is reduced because the operator no longer has to search for the ruled area which was used on the original slide. It is only necessary to locate the ruled line and by means of a mechanical stage, make a traverse to the line on the opposite side of the top piece (D), move the slide laterally for the width (or more) of the field and make a second traverse back to the original line.

(*b*) The risk of overlapping traverses is considerably reduced and, with ordinary care, is completely eliminated.

(*c*) It is simple to double the volume of fæcal suspension examined by making two further traverses. For low egg counts this provides an opportunity to record values lower than 200 eggs per gram.

(*d*) The chance of contamination from fæcal samples in adjoining counting chambers is eliminated by the presence of the troughs (F). In the original slide there was sometimes a flow of fæcal suspension over the supports if an excess of suspension was run into the counting chamber.

(*e*) The modified slides with the projecting end platform provide a better " grip " for the arms of the mechanical stage.

(*f*) The new type of counting chamber may be cleaned more readily than the original type. A glass slide may be inserted in the space between the top piece and the platforms in order to remove accumulated debris.

4. References

Gordon, H. McL., and Whitlock, H. V. (1939).—*J. Coun. Sci. Ind. Res.* (Aust.) **12**: 50.

Kauzal, G. P., and Gordon, H. McL. (1941).—Ibid. **14**: 303. **14**: 303.

Whitlock, H. V. (1943).—Ibid. **16**: 215.

A Method for Staining Small Nematodes to Facilitate Worm Counts

*By H. V. Whitlock**

Summary

Small nematodes may be stained with an aqueous iodine solution and the fluid in which they are suspended decolourized by the addition of sodium thiosulphate solution.

1. Introduction

The counting of small nematodes such as species of *Trichostrongylus, Strongyloides, Ostertagia, Cooperia,* and the immature stages of larger worms such as *Haemonchus contortus,* is often difficult owing to their size and semi-transparent appearance. Further, the worms are often mixed with a good deal of ingesta which may not be removed even by repeated sieving and washing.

2. Method

The worms are collected from the alimentary canal by a combination of washing and scraping. A piece of apparatus, similar to that described by Goldsby and Eveleth (1946)† for the collection of worms, is being developed. The watery or saline suspension containing worms and debris may be sieved and washed several times to remove colouring matter and the finer particles of ingesta, taking care to use sieves having a mesh sufficiently fine to prevent loss of worms.

The washed worms and large pieces of ingesta are then made up with physiological saline to a volume dependent on the number of worms present—the number being roughly estimated at this stage so that the samples drawn off for counting will not contain so many worms that counting will be difficult.

The suspension is mixed by stirring and shaking and a series of samples, in volume 5 or 10 ml., is drawn off quickly by means of a wide-mouthed pipette (Fig. 1). The suspension should be well shaken between the drawing off of successive samples because the worms sink quickly.

Each sample is expelled into a separate petri dish which should have a flat base. The dish is placed on a piece of white paper ruled with lines or squares to facilitate counting.

To the sample in each dish a few drops of a concentrated aqueous solution of iodine (30 g. iodine, 40 g. potassium iodide, 100 ml. water) is added. After 3–5 minutes the worms are stained a deep brown. Debris and the suspending fluid are also stained. The preparation is then "decolourized" or "cleared" by adding a 5 per cent. solution

* An officer of the McMaster Animal Health Laboratory, Sydney, Division of Animal Health and Production.

† Goldsby, Alice I., and Eveleth, D. F. (1946).—*Vet. Med.* 41: 398.

of sodium thiosulphate ("hypo") drop by drop with stirring. Just sufficient of the "clearing" solution is added to remove the brown colour from the fluid and to reduce the colour of the debris. The brown worms then show up prominently against the white background.

The worms should be counted immediately because their colour fades fairly quickly. Addition of an excess of sodium thiosulphate solution causes rapid decolouration of the worms, but if this happens they may be re-stained by adding further quantities of the aqueous iodine solution.

The mean of a number of counts is taken and the total is estimated according to the proportion between the samples and the volume from which they were withdrawn.

3. Other Uses of the Method

Demonstration of small worms to stockowners at field days and to students in practical classes is facilitated by staining in the manner described.

The worms may be stained *in situ* on the bowel wall for demonstration purposes. A convenient method for showing nematodes of the small intestine of sheep is to remove 12–18 inches of gut from the first 10–15 feet of the duodenum, which is the usual site of *Trichostrongylus* spp., and turn it inside out on a length of glass tubing fitted with a rubber ring at one end to facilitate the eversion. The specimen, with the mucosa and worms thus exposed is then dipped into a tall narrow vessel containing the concentrated aqueous iodine solution and allowed to remain there for a few minutes. It is then withdrawn and dipped into a similar vessel containing sodium thiosulphate solution which, in a few seconds "decolourizes" the mucosa, leaving the deeply-stained worms prominently displayed.

4. The Sampling Pipette

A simple pipette (Fig. 1) is readily made. The barrel (A) is a piece of glass tubing, drawn out to give an opening with a diameter of approximately 1 cm. The plunger (B) is a test tube selected to

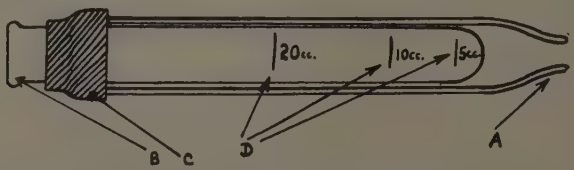

FIG. 1.—A, barrel; B, plunger; C, connecting piece; D, graduation marks.

fit fairly freely inside the barrel. The connecting piece (C) is made of soft rubber tubing through which the plunger may be drawn up and pushed down, aided if necessary by lubrication with liquid paraffin or vaseline. The pipette is calibrated with measured volumes of fluid and marked (D) at convenient levels.

Notes on Some Parasitic Actinian Larvae, and One of Their Host Medusae, in Australian Waters

*By M. Blackburn, M.Sc.**

Summary

Actinia clavus Quoy and Gaimard, an actinian with larvae parasitic on medusae, has been rediscovered and further described. The species is referable to *Peachia,* and is now recorded from Victorian and Tasmanian waters, but the adult form is still unknown. There are three known host medusae, of which one, *Cyanea capillata* (L) var. *marginata* v. Lendenfeld, is further described and newly recorded from Victoria and Tasmania.

In the course of studies on the Australian marine plankton, the writer noticed actinian larvae, associated with medusae, in three batches of material. The details of the collections are as follows:

(*a*) From horizontal tows of the "Discovery" N200 plankton net at two stations off Babel Island in the Furneaux Group, off north-east Tasmania, on the same day in November 1938. One station was within and one outside the boundary of the continental shelf. The depths of the tows were 25 and 100 metres respectively, but the nets were hauled up without closing. There were several specimens in the shallow water collection, but only a few in the other. The collections also contained specimens of an *Aequorea* (*Leptomedusae*) to which the actinians had been attached. There were none still attached when the material was studied, but some were still adhering to fragments of *Aequorea.*

(*b*) From surface horizontal tows of the "Discovery" N70 plankton net in various parts of the D'Entrecasteaux Channel (south-east Tasmania) in January 1945. Three actinians were found inside two of the adradial pouches of a specimen of *Cyanea,* and others were loose in jars containing *Cyanea,* from which they had probably become detached when killed with formalin. The internal specimens were actually noticed before killing.

(*c*) From a surface horizontal tow of the N70 net in Hobson's Bay, Port Phillip, Victoria, in September 1947. One actinian was adhering to the mouth-curtains of a *Cyanea.*

The actinians were all of the same species, and this and the *Cyanea* have been identified. Several points of interest as regards the nomenclature, morphology, and distribution of the two forms are dealt with here. The *Aequorea* material was in bad condition and could not be named. It is convenient to mention the *Cyanea* first.

Class: Scyphozoa
Order: Semaeostomeae
Family: Cyaneidae

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* An officer of the Division of Fisheries.

Cyanea capillata (L.) var. marginata von Lendenfeld 1884

Cyanea annaskala v. Ledenfeld var. *marginata* v. Ledenfeld 1884, p. 928; 1887, p. 21; Mayer 1910, p. 602; Stiasny 1921, p. 8.

? C. muellerianthe Haacke 1887, pp. 605–14, pl. xxxvi.; Stiasny, loc. cit.

The *Cyanea* material of collections (*b*) and (*c*) was referable to this form. The general description is that of *C. annaskala* according to von Lendenfeld (1882; 1884, p. 275), Mayer (loc. cit.), and Stiasny (1931, pp. 31–6). The range of bell diameter was about 30 to 90 mm., and only the smaller ones had large nettle-warts conspicuous on the exumbrella. The arrangement of the branching ends of the radial pouches of the coelenteron, and of the "bursal septa" which separate the pouches, agreed well with that figured by Stiasny. This is not quite the same as in von Lendenfeld's figure (1882, pl. xxviii.), in which the bursal septa are straight. The tentacles were numerous in even the smallest specimens, but were all contracted or broken in the preserved material; some individuals seen swimming had tentacles at least 2 feet long. Gonads were prominent in even the smallest individuals.

As to colour, the bell itself had none, but the endoderm of the coelenteron was a deep reddish or purplish-brown (but much paler in the smallest specimens). This was not continued into the branching ends of the radial pouches in the marginal lappets. The gonads were pinkish-brown, to light yellowish-brown in the smallest individuals. The tentacles were white. The mouth-curtains were colourless except for a thin border of purplish-brown at their edges, but in some specimens this was very faint and not continuous over the whole margin.

Some smaller stages of the same species, not associated with actinian larvae, were taken in large numbers in surface plankton tows in Hobson's Bay in December 1944. They ranged from about 5 to 15 mm. in bell diameter, and were virtually colourless except for the thin band of purplish-brown on the mouth-curtain margins. There were relatively few tentacles in each cluster, and those mostly arranged in only one row. Most specimens of over 7–8 mm. diameter had the full number of marginal lappets found in the adult. Nettle-warts were prominent on the exumbrella. The gonads were not very obvious except in the largest specimens. Still smaller *Cyanea,* at the ephyra stage, were taken in plankton hauls in the Huon River (which flows into the D'Entrecasteaux Channel) in October 1945. These were of maximum diameter (including the extended lobes) about 3–5 mm., and had gastric cirri but no tentacles or mouth-curtains. There were only sixteen lappets at this stage. The indications thus are that the medusae are produced in the spring in shallow estuarine waters.

The above-mentioned colour pattern agrees with that in var. *marginata* of von Lendenfeld's *C. annaskala,* whereas the specimens that formed the basis of his original description of the species (loc. cit.) had the mouth-curtains bright purple throughout. Von Lendenfeld subsequently styled this first form var. *purpurea* (1884, p. 928). He found *purpurea* in Port Phillip and *marginata* in Port Jackson.

The nomenclature of *Cyanea* is rather involved, and many species have been described that seem to differ in little but colour, which is in any case rather variable. Mayer (1910, p. 596) believed there were only two good species, *C. capillata* (L.) from the northern temperate and Arctic waters, and *C. annaskala* from the southern temperate waters. Since he wrote, there have been many records of *Cyanea* from the tropics, breaking down the geographical distinction that was intended, and it is now thought that all known medusae of this genus are varieties of the single species *capillata*. This was the view taken by Stiasny (1919, p. 87; 1921; pp. 7–8) and Bigelow (1928, pp. 520–21). Stiasny later indicated (1931) that the structural features of *annaskala* fell well within the range of variation of *capillata* in the broad sense, leaving only the colour of the mouth-curtains as a distinct character. Von Lendenfeld's original *Cyanea* (his *annaskala* var. *purpurea*) should thus be known as *C. capillata* var. *annaskala*; and his second variety (*annaskala* var. *marginata*), the one dealt with here, as *C. capillata* var. *marginata*.

Mayer (loc. cit.), placed a number of other forms in the synonymy of *C. annaskala,* but the only one of these (or of the other various forms of *Cyanea*) that seems at all close to var. *marginata* is *C. muellerianthe* as described by Haacke (1887) from St. Vincent's Gulf, South Australia. This is quite the same except that the bell and mouth-curtains are rose-coloured, apart from the dark fringe. Von Lendenfeld (1888, p. 218) and Maas (1903, p. 28) also thought this was *C. annaskala,* but Stiasny (1921), while admitting the very close relationship between the two, was less certain. Later (1922, p. 521) Stiasny described another specimen, taken from between Sydney and Melbourne, and referred it to *muellerianthe*. The relationships of this animal (colour "weisslich hyalin") are more doubtful.

Thus, including the present new Tasmanian and Victorian records, the range of var. *marginata* is from Port Jackson to southern Tasmania and to Port Phillip, and possibly westward to St. Vincent's Gulf. Var. *annaskala* is known from Port Phillip, and also from the neighbourhood of Sydney if the specimens described by Stiasny (1931) are included; since they had the mouth-curtains a uniform brownish-red, they were certainly closer to *annaskala* than *marginata*. There are other Australian forms that are to be regarded as still other varieties of *C. capillata,* namely: *C. rosea* Quoy and Gaimard, from Port Jackson; *Desmonema rosea* Agassiz and Mayer, from St. Vincent's Gulf; *C. capillata* var. *mjobergi* Stiasny, from north-western Australia; and the other east Australian form mentioned above, referred by Stiasny to *C. muellerianthe*. The characteristics of the first three are given by Stiasny (1921, pp. 9–11). Other varieties from the Pacific, and elsewhere, are also distinct in various ways.

The actinian larvae are now discussed. The systematic position of the species, and its synonymy, are as follows:

Class: Anthozoa
Subclass: Zoanthactiniaria
Order: Dodecactiniaria
Suborder: Actiniaria
Tribe: Nynantheae
Subtribe: Athenaria
Family: Ilyanthidae

Peachia clava (Quoy and Gaimard 1833)

Actinia clavus Quoy and Gaimard 1833, p. 150, pl. x., figs. 6–11.
Iluanthos clavus Milne–Edwards 1857, p. 284.
Philomedusa clavus Andres 1884, p. 114.
Halcampa clavus Haddon 1887, p. 476; Pax 1912, pp. 310–12, pl. i., fig. 1, text-figs. A, B.
Bicidium clavus McMurrich 1913, p. 969.
Halcampoides clavus Stephenson 1922, p. 253.
Halcampa (?) sp. Dendy 1889, pp. 112–4.
non *Halcampa clavus* Hertwig 1882, pp. 92–7, pl. iii., figs. 1, 4, 10, pl. xii., figs. 8, 9, 11, pl. xiii., figs, 2, 4–7; Tizard and Murray 1882, p. 674; Haddon 1889, p. 336; Appelhöf 1896, pp. 12–4.

The animals ranged from about 2·5 to 8 mm. in length, were pinkish-brown in colour and had twelve (rarely only eleven) short tentacles. In most specimens there could also be recognized the partly-everted actinopharynx with twelve lobes, just inside the circle of tentacles, and three of these appeared to contribute to the formation of a prominent groove or gutter leading to a conspicuous siphonoglyphe, and to the rudiments of a conchula at the outer end of the groove. This all pointed to some species of *Peachia,* a genus well known for its medusophilous larvae.

There have been recorded from Australian waters two species (both described, in part or whole, from larvae) which have been or might be referred to *Peachia.* These are *Halcampa clavus* (as called by Pax, who re-examined the type material) from Bass Strait, and *Peachia hilli* Wilsmore from New South Wales. By making hand-cut sections of several specimens at different levels along the column, it was found that there were six pairs of mesenteries, of which all were attached to the actinopharynx in its upper portion. However, the mesenteries of the fifth and sixth couples (see Stephenson 1928, p. 77) were not attached further down although the others were, a situation similar to that described by Haddon (1887, p. 478) for the larvae of *Peachia hastata* Gosse (wrongly called "*Halcampa chrysanthellum*" by Haddon, see Stephenson 1935, p. 96). Now in both the above-mentioned Australian species there are only twelve mesenteries in the larva, but whereas in *Peachia hilli* those of the fifth and sixth couples are not attached to the actinopharynx at all (Wilsmore 1911, pp. 43–4), in *Halcampa clavus* they are attached at some level, as shown in text figure A by Pax (1912). Wilsmore was quite specific on the point and was aware of its importance, and as the larva examined by her was considerably larger than any of the present specimens, it seems certain that these cannot be *P. hilli.* Pax's description was brief, and contains nothing to suggest that any of the mesenteries were free from the actinopharynx at any level. However, his remarks indicate that his studies were not very detailed, and he might easily have overlooked this point as he did others, e.g. the obvious distinction between his species and Hertwig's *clavus* from Kerguelen. His material (i.e. Quoy and Gaimard's types) was fairly comparable as regards size to the specimens studied here, and there is nothing either in his or the original authors' descriptions and figures, as far as they go, that could not apply to the present material. No other specimens have been described. The *Astrolabe* specimens were taken in Bass Strait, "engagés dans les tentacles d'une Méduse". As some of the present

specimens were also from the Bass Strait region it is almost certain that they refer to the same species, the *Actinia clavus* of Quoy and Gaimard, which must now be referred to *Peachia* on account of the features associated with the siphonoglyphe, and not previously observed.

With regard to these particular features, the position is shown in Fig. 1, in views of three larvae (from the Babel Island collections) from above and from the side. The smallest one, I (2·5 mm. long), has already the twelve tentacles and twelve actinopharyngeal lobes, and the lower part of the actinopharynx is open and the siphonoglyphe can be seen some distance down. Leading to that there is a distinct open groove, of which one actinopharyngeal lobe (of the ventral directive endocoel) constitutes the floor and the two adjacent lobes the sides. Sectioned specimens at this length show that the twelve mesenteries are already well developed. The next largest, II (3·5 mm. long), is much the same, except that the two lateral lobes are practically in contact and much of the groove is almost covered over, though a prominent opening remains towards the edge of the disc. In the largest specimen, III (8 mm.), there are signs around this opening of the appearance of special lobed structure which is without doubt a developing conchula. There is a small papilla growing out from each of the lateral lobes. Unfortunately, the development cannot be followed further in this material, but with a somewhat further growth these papillae, together with the small lobe flooring the groove, could constitute a three-lobed conchula similar to those in other species of *Peachia* (see, for example, Stephenson 1928, p. 68; Panikkar 1938, pp. 196–7). Other lobes might be added subsequently. Even so far as the present observations go, however, they serve definitely to show that the genus in question is *Peachia*, of which such features are characteristic (Stephenson 1921, p. 574; 1928, pp. 29–30).

There are several species of *Peachia* in other seas, but even considering only the larvae, the present form is obviously distinct from most or all of them. *P. koreni* McMurrich (1893, p. 144) from Argentina, and *P. neozelanica* Carlgren (1924, p. 187) from New Zealand have only eight and ten tentacles respectively in individuals larger than those studied here. These, together with the incompletely described and dubious *P. carnea* Hutton (1879, p. 275) from New Zealand, are the only species known solely from free-living stages. All the others are known in the medusophilous larval stage as well as free-living, or from the former only. These others are *P. hastata* Gosse from European waters (probably including other supposed European species, see Stephenson 1935), *P. quinquecapitata* McMurrich (1913, pp. 963-7) from the North Pacific, *P. tropica* Panikkar (1938) from India, *P. chilensis* Carlgren (1931, pp. 37-8) from western South America and *P. parasitica* (Agassiz) from eastern North America. The present specimens of *P. clava* differ from *hastata* in having twelve (occasionally only eleven) tentacles at under 3 mm. length (cf. Haddon 1887); from *quinquecapitata* in having twelve prominent mesenteries at a similar length (cf. Uchida 1938, p. 286); from *tropica* in having the tentacles developed long before the conchula; from *chilensis* in not having the mesenteries of the fifth and sixth couples notably weaker than the previous eight, in specimens of comparable or smaller size; and from *parasitica* at least in colour (cf. Verrill 1866, p. 31). The distinction from *P. hilli* has been mentioned already.

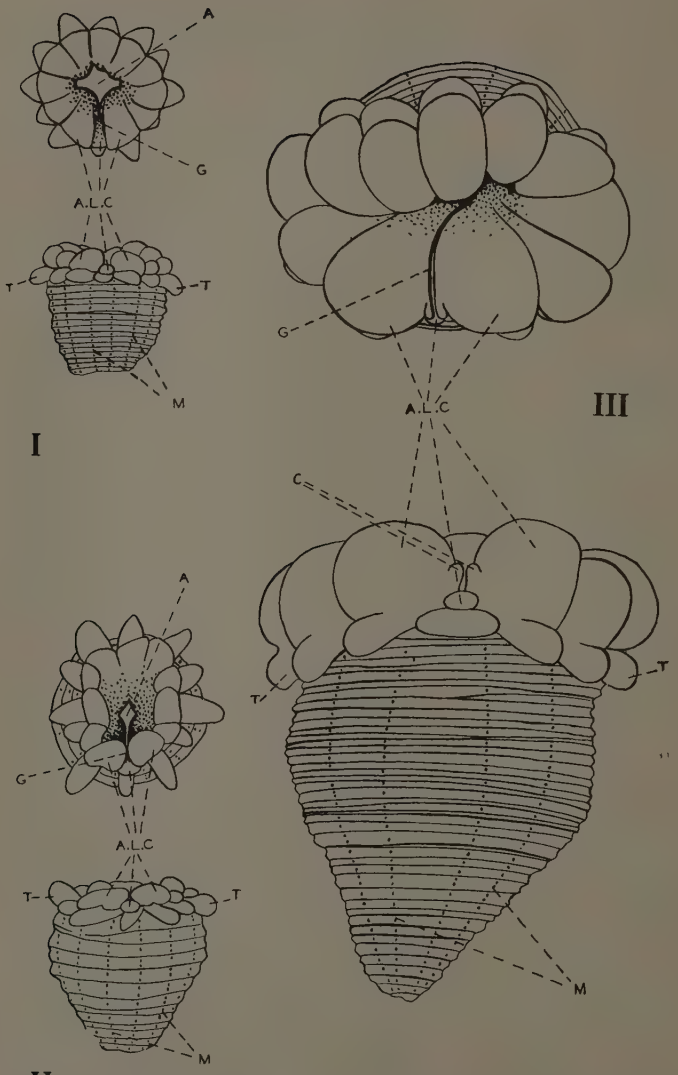

FIG. 1.—Three specimens of *Peachia clava*, seen from above and from the side: I, 2·5 mm. long; II, 3·5 mm.; and III, 8·0 mm.

A, cavity of actinopharynx; A.L.C., actinopharyngeal lobes contributing to formation of conchula; G, groove formed by same, leading to siphonoglyphe; C, elements of developing conchula; T, tentacles; M, position of mesenteries as seen externally. For further explanation see text.

The larval actinians found by Dendy (1889) in Port Phillip Bay, attached to the mouth-curtains of a medusa which from his description was undoubtedly *Cyanea capillata* var. *annaskala,* were certainly the same as the present species. Thus *Peachia clava* has three known hosts, *C. capillata marginata, C. c. annaskala,* and an unnamed *Aequorea.* The known range of the species is now from Port Phillip through Bass Strait to southern Tasmania. The adult stage has yet to be discovered.

It has been mentioned that some of these larvae were found in the radial pouches of a *Cyanea. P. hilli* has also been discovered in the radial canals of a scyphozoan medusa, the rhizostome *Catostylus* (*Crambessa*) *mosaicus* (Quoy and Gaimard), by Badham (1917). According to that author the actinians eventually bore through to the outside of the host and release themselves, prior to assuming a benthic adult existence. Carlgren described *P. chilensis* "Im Innern einer grossen Medusa". Stuckey (1909, p. 397) noted an unknown actinian, which could have been a *Peachia,* from a radial canal of a large scyphozoan in New Zealand. Other records of *Peachia* larvae with medusae refer to individuals adhering to the outside of the host, which is more usually one of the Hydromedusae.

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Siliceous Inclusions in Wood in Relation to Marine Borer Resistance

By G. L. Amos, M.Sc., and H. E. Dadswell, D.Sc.**

Summary

Australian turpentine (*Syncarpia laurifolia* Ten.) has a world-wide reputation for marine borer resistance. Recently, however, it has been reported (Edmondson 1947) that timber from this species grown in plantations in the Hawaiian Islands had a comparatively low resistance. Specimens of both Australian and Hawaiian grown turpentine were therefore examined and it has been shown that the Australian material had numerous siliceous inclusions in the ray cells and a high silica content (average 0·59 per cent.) in contrast with the comparative lack of inclusions and low silica content (average 0·09 per cent.) of the Hawaiian-grown material. This comparative lack of silica has been suggested as the reason for the low marine borer resistance. Support for this suggestion has been derived from the observation that various Australian and New Guinea timbers of known marine borer resistance also contain many siliceous inclusions, and from evidence in the literature relating silica content and marine borer resistance. Alternate theories regarding the possible effect of silica on the marine borers have been discussed and reference has been made to the mechanism by means of which the plant might take up silica.

1. Introduction

Recently timbers of the South-West Pacific Area have been examined with the particular object of determining which species are characterized by the presence of siliceous inclusions in the ray cells. This survey was originally planned to determine to what extent these inclusions could be used for identification purposes but, as part of this broader project, it was considered of value to review the work of van Iterson (1933) who, in a paper on the significance of wood anatomy in relation to the preservation of marine structures against teredo, suggested that the presence of quantities of silica in wood was highly significant. In his reference to the marine borer resistant timber "manbarklak" (*Eschweilera longipes* (Poit.) Miers) he observed that the ray cells contained rather large inclusions of silica, one inclusion occurring in every ray cell. Other woods from the forests of Dutch Guiana, which were also marine borer resistant, contained silica inclusions of a similar kind. Experiment confirmed that woods that contained 0·5 per cent. silica or more and were sufficiently compact showed a remarkable resistance against the attacks of teredo, whereas compact woods without siliceous inclusions were not resistant.

In a recent paper by Edmondson (1947) it was reported that "turpentine" (*Syncarpia laurifolia* Ten.) grown in the Hawaiian Islands did not possess the same resistance to teredo and limnoria as did the Australian-grown timber. The physical and anatomical contrasts between the Australian and Hawaiian specimens were that the former were darker and denser than the latter and showed evidence of more extensive gum deposits in the vessels. It was suggested that lack of age and the rapidity of growth of the Hawaiian material as well as the absence of gum deposits in the vessels might be contributing factors to the low resistance.

* An officer of the Division of Forest Products.

In the survey mentioned above, a number of species of the Myrtaceae including *Syncarpia laurifolia* had been observed to contain siliceous inclusions in the ray cells. It was therefore considered pertinent to examine Hawaiian-grown specimens of this species in comparison with the Australian-grown specimens in respect to the criteria for marine borer resistance advanced by van Iterson. This was rendered possible by the courtesy of Dr. C. H. Edmondson of the Bernice P. Bishop Museum, Honolulu, who very kindly forwarded by air a number of the Hawaiian-grown specimens which had actually been service-tested by immersion.

2. Experimental Procedure

In both the Hawaiian specimens and the available Australian specimens, silica was estimated in the normal manner by igniting the wood in a platinum crucible, converting the ash to sulphates, and volatilizing the silica as silicon tetrafluoride using a mixture of hydrofluoric and sulphuric acids. The loss in weight sustained by the sulphated ash as the result of hydrofluoric-sulphuric acid treatment gave the quantity of silica, which was expressed as a percentage of the oven-dry weight of the wood. The basic density of each specimen was determined; for this purpose the ratio (oven-dry weight)/(volume when soaked to maximum volume) was obtained and the result expressed as pounds per cubic foot. Results of both basic density and silica content are given in Table 1.

TABLE 1.—SILICA CONTENT AND BASIC DENSITY OF SPECIMENS OF *Syncarpia laurifolia* Ten. FROM AUSTRALIA AND HAWAII

Australian Specimens			Hawaiian Specimens*		
Origin	Silica Content Percentage of O.D. Wood	Basic Density (lb./cu. ft.)	Sample Marking	Silica Content Percentage of O.D. Wood	Basic Density (lb./cu. ft.)
Beecroft, N.S.W. ..	0·33	38·4	(*a*) Sapwood ..	0·050	30·6
Coff's Harbour, N.S.W. ..	0·43	45·9	(*b*) Transition Sap/heart	0·075	34·6
Coff's Creek, N.S.W. ..	0·52	43·3	(*c*) Heartwood	0·075	36·8
Termeil, N.S.W.	0·58	44·5	(*d*) Heartwood	0·128	38·1
Coff's Harbour, N.S.W. ..	0·42	42·7	(*e*) Sapwood ..	0·070	38·2
Craven State Forest, N.S.W.	1·24	39·0	(*f*) Heartwood	0·070	43·1
Durundur, Q.	0·42	44·8	(*g*) Heartwood	0·170	35·7
Durundur, Q.	0·37	43·2			
Unknown	0·68	..			
Unknown	0·79	..	Average	0 091	36·7
Unknown* (specimen from Dr. Edmondson) ..	0·75	42·2	Bark ..	0·035	..
Average	0·59	42·7			

* Specimens through courtesy of Dr. C. H. Edmondson of the Bernice P. Bishop Museum, Honolulu.

The bulkiness of the ash obtained from equal weights of Australian and Hawaiian wood was markedly different, being much greater in the case of the Australian material. In a further experiment equal weights of heartwood from the two sources were submitted to wet combustion using sulphuric and nitric acids and a little hydrogen

peroxide. The inclusions from both digestions were suspended in equal volumes and drops of these suspensions were placed on microscope slides for examination. The suspended material in each case was microscopically identical with the ray cell inclusions and was chemically identified as consisting of more than 98 per cent. silica. However, its relative abundance was markedly different. The inclusions from the Hawaiian specimen were small and sparse whereas those from the Australian specimen were larger and more numerous (compare Plate 1, Figs. 1 and 2).

Comparative microscopic examinations of the Australian and Hawaiian specimens were also carried out with particular reference to (i) silica deposits and (ii) gum deposits in vessels. The silica inclusions were readily distinguished in the ray cells of the Australian timber by their size and abundance (see Plate 1, Fig. 3) but were noted to be much smaller and less numerous in the Hawaiian specimens (see Plate 1, Fig. 4).

Approximately twenty specimens of Australian-grown *Syncarpia laurifolia* from various localities in New South Wales and Queensland were examined microscopically for gum deposits in the vessels. These deposits were not extensive and appeared to be the exception rather than the rule. Where observed they seemed to be of the same chemical type as the material filling the ray cells which is extensive in both the Hawaiian and Australian specimens examined. It is difficult to imagine that the little additional gum in the vessels can have any marked effect on marine borer resistance since its abundance in the rays is no deterrent.

In view of the above results and observations, the conclusions reached by Edmondson as to the reasons for the lack of resistance of the Hawaiian-grown *Syncarpia laurifolia* must be reconsidered. It is apparent that the suggestion of gum deposits in the vessels has little or no bearing on the problem. The question of relative densities might, however, be pertinent since van Iterson noted that a certain degree of compactness is of assistance in reducing the rapidity of attack by marine borers. The basic densities of the Hawaiian specimens, as recorded in Table 1, are appreciably lower than those obtained for the Australian specimens selected for comparison purposes and are, in fact, below or at the lower limit of the 95 per cent. probability range for the species quoted by Greenhill and Dadswell (1940), viz., 38·6–49·4 lb./cu. ft., mean 44·0 lb./cu. ft. This is to be expected from young fast-grown material and may have some bearing on the results obtained by Edmondson. However, in view of the reputation for resistance that the Australian timber has achieved, it is suggested that a less dense Australian specimen might well be more resistant than a heavier Hawaiian specimen. It seems more probable that the differential resistance of the timbers of the two different origins is attributable to the empirically established criterion of silica content. From Table 1 it will be seen that the Australian specimens on the average contained six to seven times as much silica as did the Hawaiian specimens and in addition were all close to or above the specification for borer resistance adopted by the Dutch workers, namely 0·5 per cent. silica in a relatively dense wood.

Further information to substantiate this relationship of silica content and marine borer resistance was obtained from the examination of (i) species which had been found resistant to marine borers in Queensland waters, and (ii) wood specimens from marine structures erected in New Guinea waters during the Pacific War.

Watson and co-workers (1936) listed the four most resistant Australian timbers in the following order: *Syncarpia laurifolia* Ten., *Tristania suaveolens* Sm., *Xanthostemon pachyspermus* F.v.M., *Syncarpia hillii* F.M.Bail. Examination of available material of each of these species, all of which incidentally belong to the family Myrtaceae, revealed the presence of siliceous inclusions in the ray cells (see Plate 2, Figs. 1 and 2). Silica was not observed in specimens of certain other species which were tested and which in some cases showed some degree of resistance, e.g., *Eucalyptus tereticornis* Sm. In these tests *Eucalyptus paniculata* Sm. (grey ironbark), a very dense timber with an average air-dry weight of 68·6 lb./cu. ft., was readily attacked, a fact which supports the comment of van Iterson that compact woods are not resistant to marine borers by virtue of their compactness alone.

Shillinglaw and Moore (1945) examined a number of marine structures about the New Guinea coast during 1945 for the Australian Army. As a result they recommended that the following four species be used because of their marine borer resistance:

Syncarpia laurifolia Ten.—Approximate life 10-20 years.

Xanthostemon sp.—kasi kasi.—Approximate life 10-20 years.

Anisoptera polyandra Bl.—garawa.—Approximate life more than 5 years.

Cocos nucifera L.—coconut.—Approximate life more than 5 years.

Examination in these laboratories of samples from the actual timbers inspected showed that the first three contained abundant siliceous concretions in the ray cells (see Plate 2, Fig. 3) and that in the coconut there were siliceous concretions in the tissues surrounding the vascular bundles. Other woods showed good resistance but insufficient samples were obtained to draw firm conclusions and in addition the specific identity of some could not be determined. However, it can be stated that representatives of the genera *Burckella, Evodia,* and *Planchonella,* which were considered resistant, all contained silica concretions in the ray cells. On the other hand, specimens of various genera including dense representatives of *Rhizophora* and *Bruguiera* were non-resistant and possessed no silica inclusions. In addition to the above evidence there are references in recent literature (e.g., Horn 1948) to the marine borer resistance of timbers in which silica inclusions are abundant.

It is not intended to suggest in this paper that marine borer resistance is attributable only to silica inclusions; some timbers which are reputedly resistant (e.g., *Eusideroxylon zwageri* T. et B.)* have no such inclusions and in these cases the resistance must be due to some other factor such as the presence of toxic materials. However, it is

* In a recent publication, Revue Internationale du Bois (1947) 14: 156, this species has been reported as completely destroyed by teredos after 5 years' immersion.

suggested that the presence of silica inclusions is one important criterion and that a survey of timbers for this particular feature may prove of considerable value, as the knowledge gained might assist materially in determining the most suitable species for marine structures. The density of the wood should, of course, be taken into account in addition to its silica content and further evidence is needed regarding the minimum figure of 0·5 per cent. silica empirically selected by the Dutch workers.

3. Mechanism of Resistance

A suggestion as to the mechanism of resistance in woods containing siliceous ray inclusions has been made by van Iterson on a purely mechanical basis, namely that the gritty particles in the wood cause damage to the minute teeth on the valves of the borers' shells which cannot be replaced at a sufficiently rapid rate to compensate for their removal. He presented no evidence to support this hypothesis. The amorphous silica inclusions observed are precipitated under mild conditions of temperature and acidity and it is difficult to imagine that their hardness is of sufficient magnitude to provide the valves of the borer with very marked opposition. Another property of these inclusions is that they are soluble in very dilute alkali (e.g., 1 per cent. sodium carbonate), a further reflection of the mild temperature conditions under which they were deposited. Moreover it has been established (San Francisco Bay Marine Piling Committee 1927) that teredine borers digest a considerable portion of the wood borings (up to 80 per cent. of the cellulose) which all pass through the alimentary system of the animal, remaining within it for a considerable period. It is suggested that, if exposed to mild alkaline conditions in the alimentary tract for any appreciable period, a considerable quantity of the silica inclusions would dissolve and the consequent metabolic upset in the organism would possibly affect its normal function to a marked degree, either through influencing its capacity to digest cellulose or by being absorbed as silicate, thus influencing the general life activities of the organism.

It yet remains to determine by what mechanism the plant takes up silica, and to account for a number of observations which are at first sight incompatible. Petrucci (1903) suggested that the nature of mineral inclusions may be in direct accord with the nature of the soil in which the plant has grown, and maybe also with the climatic conditions under which it is found. He was concerned with the common observation that woods which contain deposits of calcium oxalate rarely contain silica and vice versa, an observation which has led many investigators to use terms such as " calciphilic " and " calciphobic " with reference to the two types. This conception receives some support in that edaphic factors are ecologically important in determining the distribution of many species. That soil and climate are not the sole determinants of the type of mineral inclusions is evidence in that trees of various species subject to the same soil and climate in New Guinea have different mineral inclusions. Examinations were made of the woods from different species which were known to have grown practically side by side. In one case involving two species of the Dipterocarpaceae, it was found that in one, *Anisoptera polyandra* Bl., siliceous inclusions were present in practically all the ray cells and in the other, *Hopea papuana* Diels, silica was absent but

calcium oxalate crystals were present in the wood parenchyma and procumbent ray cells. In a second case the species examined belonged to different families and in one, *Evodia elleryana* F.v.M., siliceous inclusions were present in the ray cells; in the other, *Euroschinus papuanus* Merr. and Perry (mspt.), silica was absent but calcium oxalate crystals were present in the ray cells. Numerous similar examples could be quoted. Further, Petrucci observed that there were some timbers such as *Cotylelobium* sp. and *Coelostegia borneensis* Becc. in which both siliceous masses and crystals of calcium oxalate are encountered together in the same tissue, albeit not within the same element, and this observation has been confirmed with some New Guinea timbers of the family Burseraceae. The fact that the stinging hair of *Urtica* can metabolize both silica and calcareous substances, i.e., in the one element (Haberlandt 1928), shows that where materials serve a functional purpose, the concept " calciphobe " or " calciphile " cannot be applied even on the level of single cells.

The inclusions in the wood rays are physiologically inert and do not perform any function. That two adjacent trees will deposit different types of inclusions, one disposing of a surplus of cations (calcium oxalate) and the other of a surplus of anions (silica) indicates a fundamental difference in the absorption mechanism between the two trees, independent of soil conditions, and suggests a specific difference in the protoplasm of the two plants. Lundegårdh (1947) has drawn attention to the importance of the plasma membrane in the uptake of mineral materials, which suggests that the electrochemical nature of the interface between the root hair protoplast and the soil solution exercises a discriminating influence on the type of mineral materials absorbed. In plants which absorb such an excess of silica, the protoplasmic surface of the root hair probably has a preponderance of hydroxyl groups which it exchanges with the medium for silicate ions, as distinct from the normal type which is slightly acidic in character, the ion activity of the surface thereby producing a situation favourable to the absorption of cations. It is conceivable that other plants, in which the plasma membrane contains an abundance of both acidic and basic groups of an ionizable nature oriented towards the surface of the protoplast, will take up excesses of both anions and cations, thereby accounting for the plants which deposit excess calcium oxalate and silica.

It is of interest to note that Osterhout (1945) was able to reverse the charge on the plasma membrane from negative (cation absorbing) to positive (anion absorbing) by treatment with potash, and to consider this in relation to Němec's findings (1940) that treatment of spruce seedlings with potassium salts enhanced the uptake of silica. Whether or not it would be possible to increase the silica content of the Hawaiian plantations of *Syncarpia laurifolia* by treatment with potassium fertilizers could be decided by experiment only, but from theoretical considerations it would appear that such an experiment would be worth trying.

It is appreciated by the authors that much of the physiological work necessary to elucidate the problems of uptake of silica and its toxic action on teredine borers is beyond the scope of the Division of Forest Products, but in view of its economic importance, it is hoped

that interest will be stimulated among workers who have the facilities to investigate more fully the various phases which have been left on a speculative level.

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An Automatic Machine for Determining Clay Substance in Moulding Sands

By G. V. Cullen, Dip. Met., Dip. Chem. Eng., and J. E. Marshall, F.M.T.C.†*

Summary

An automatically operated machine which separates by sedimentation particles of different sizes is described. Its application to the determination of A.F.A. clay substance in moulding sands is discussed. Results obtained by the machine and the "hand" methods are compared.

1. Introduction

A moulding sand consists principally of silica grains and clay. When the sand is milled with a suitable amount of water, the clay is distributed as a thin film over the sand grains and forms the bond.

The accurate determination of the clay content of a sand by physical or chemical means is difficult. Since the size of the individual clay particles is small compared with that of the silica grains, however, it is possible to disperse these fine particles and separate a fraction containing the clay by one of the conventional methods based on particle size. Since the finer fraction may contain some siliceous material in addition to clay, it is called "clay substance." The upper size-limit of clay substance varies with different specifications. The Standards of the American Foundrymen's Association‡ (with which we are concerned) specify 0·02 mm.§

The A.F.A. method for determining clay substance is a sedimentation method, involving settling of the sand grains followed by removal of suspended clay substance. To 50 g. of sand placed in a "sand wash jar" (Plate 3, Fig. 1), 500 ml. of 0·15 per cent. sodium hydroxide solution are added, and the contents stirred mechanically for five minutes to deflocculate the clay. Water (27°C.) is then added until the total height is 6 in. After settling for ten minutes, 5 in. of the liquid is removed by a siphon. This process of adding water, settling and siphoning is repeated until the liquid remaining after settling is perfectly clear. The first two settling periods are each of ten minutes' duration (to avoid difficulties arising from increased viscosity and apparent density of the clay-water suspension) after which the intervals are five minutes. The A.F.A. clay substance remains

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‡ "Foundry Sand Testing Handbook. Standards and Tentative Standards." Amer. Foundrym. Ass. Fifth Ed. (Chicago, 1944).

§ A.F.A. clay is defined as "that earthy portion of foundry sand which, when suspended in water, fails to settle at a rate of 1 in. per min., and which consists of particles less than 20 microns (0·02 mm.) in diameter." At 27°C. spherical particles of quartz 0·02 mm. in diameter would settle at the above rate.

suspended and is removed. The sand remaining in the jar is dried, weighed, and the percentage of clay substance calculated from the loss in weight.

The determination of clay substance in sands containing large quantities of silt may involve as many as 100 settlings. A machine (Plate 3, Fig. 2) was therefore designed to perform automatically the routine movements of the test in a manner conforming with A.F.A. standards.

2. The Clay Substance Machine

(*a*) *Requirements*

The machine should perform the following steps:

(i) Fill the jars with water.
(ii) Stir to ensure uniform suspension of the clay substance.
(iii) Permit undisturbed settling of the " sand " for five minutes.
(iv) Remove suspended clay substance.

(i) *Filling with Water and Control of Water Level*

Water is admitted by opening a solenoid valve. When the water reaches the correct level the valve is closed by a microswitch operated by a float in a chamber connected to the inlet system. Owing to variation in pressure it has not been found practicable to control the water by a fixed time of flow.

(ii) *Stirring*

Propeller-type stirrers provide sufficient agitation, and need not be removed from the jars during the settling.

(iii) *Settling*

The timing of the settling period, and also the subsidiary periods (to be discussed later) are controlled by a synchronous electric motor driving two cams which in turn open and close microswitches.

(iv) *Siphoning*

The tubes used for filling are immersed and remain full until the end of the settling period when a second (outlet) solenoid valve opens and then they act as siphons.

(*b*) *Description of Machine* *

The washing jars (1)† are fitted into base sockets (2) and held firm by means of the set-screws (3). A $\frac{1}{8}$-horsepower, single-phase, 50-cycle, induction-type motor (4) drives pulleys (5) connecting by means of dog clutches (6) with the stirrers (7) which can be raised (7A) to insert the jars. The propeller-type stirrers rotate at 250 r.p.m., the distance of the blades from the bottom of the jars being adjusted by means of set-screws. The tubes for filling and siphoning (8) connect with the main header system (9) through rubber-sealed metal

* Blueprints may be obtained on application to the Chief, Division of Industrial Chemistry, C.S.I.R., Box 4331, G.P.O. Melbourne.

† Numbers refer to Plates 4 and 5.

couplings (10), which allow the tubes to be removed to introduce the jars and in addition allow the height of the tubes to be adjusted accurately.

The mouth of the A.F.A. type siphon is bent at right angles. Since the siphon had to remain in the liquid during settling, particles lodged in the mouth and were removed and reported as clay substance. Experiments proved that a straight siphon was satisfactory, and this type was used to overcome the difficulty.

The jars are filled by opening the inlet solenoid valve (11) which allows the water to flow through the header to the tubes. The level of the water in the jars is controlled by a float in the chamber (12) which operates a microswitch (13) and closes the inlet solenoid valve. The rate at which each jar fills is controlled by the taps (14). The graduated scale and pointers (15) attached to the taps make it possible to reproduce an established settling.

The water level can be adjusted by raising or lowering the microswitch (13) on the support (16), but it is more convenient to regulate the rate of flow of water into the float chamber by means of the tap (17).

The switch which opens the inlet solenoid valve also starts the motor (4) which drives the stirrers. Stirring continues after the inlet solenoid valve closes, until the motor is stopped at the commencement of settling. Five minutes later, a second solenoid valve (18) is opened, and the upper 5 inches of suspension are removed.

The movements are controlled by the synchronous motor (19) which rotates cams (20) and (21) once every six minutes. Cam (20) operates microswitch (22) controlling the inlet solenoid valve, and cam (21) operates microswitch (23) controlling the outlet solenoid valve. The duration of the filling and stirring period can be adjusted by means of the set-screw (24) which raises or lowers the microswitch (22). The duration of the siphoning period can be adjusted similarly by the set-screw (25). The position of the main stages in the cycle can be varied by rotating the cams with respect to each other.

The synchronous motor (26) and revolution counter (27) indicate the stage in the cycle, and record the number of cycles. A striplight (28) is placed behind the jars to facilitate observation.

(*c*) *Operation*

The microswitch (22), starts the stirrers and opens the inlet solenoid valve (11). When the water reaches the desired level the float operates microswitch (13) which closes the inlet solenoid valve. Filling requires fifteen seconds. Stirring continues (for five seconds) until the microscitch (22) breaks the circuit. After five minutes the microswitch (23) opens the solenoid valve (18) and the upper five inches of suspension is removed. Siphoning is completed in 27 seconds and eight seconds are allowed for drainage before the valve is closed. After a pause of five seconds the cycle is repeated.

3. General Discussion

(*a*) *General*

For less than four determinations, some of the jars may be removed, but to avoid adjustments to the taps it is preferable to run these jars without a sample. The present apparatus is designed to remove minus 20 micron material. A gear box in the timing mechanism would enable the separation of different sizes.

The settling period is controlled to ± 1 second, and the water level to ±1/16 inch. The water is maintained at 27°C.±½°C. Under these conditions the variation of the diameter of particles settling is limited to 1 per cent. of the calculated value.

(*b*) *Performance*

In order to compare the machine and "hand" methods five sands, representative of the types normally encountered in determining clay substances, were selected, and four samples of each sand were washed by each method. The results are set out in Table 1. A statistical analysis using a square root transformation shows (i) the variability of the two methods is similar, (ii) the difference between the means for Preston sand is significant and the difference between the means for Guildford loam and for Redhead loam highly significant. The differences between the means of the sands in question are not sufficiently large, however, to have practical significance. Hence it may be concluded that the automatic machine provides a satisfactory method for determining clay substance in foundry sands.

TABLE 1

Sample.	Hand-washed					Machine-washed				
	A	B	C	D	Average	A	B	C	D	Average
Guildford Loam ..	50·94	50·08	50·30	49·30	50·16	49·12	49·66	48·80	49·62	49·30
Glenbervie	12·00	11·68	11·70	11·72	11·78	12·22	11·98	11·74	11·98	11·98
Preston ..	15·76	15·72	15·68	15·92	15·77	16·08	16·06	16·20	15·98	16·08
Redhead Loam ..	22·40	22·14	22·40	22·16	22·28	21·60	21·14	21·70	21·28	21·43
Findon ..	1·50	1·48	1·52	1·54	1·51	1·52	1·38	1·38	1·44	1·43

The machine has been in continuous use for two years and has given no serious trouble. The original outlet solenoid valve was not new, and recently it had to be replaced. To avoid the accumulation of sediment in this valve the suggestion has been made that, just prior to closing, it should be flushed by opening the inlet valve.

(*c*) *Modifications*

The authors consider that the following modifications would improve the machine:

(1) Replacement of the gas taps (14) with needle valves for more precise control.

(2) Finer threads and a vernier attachment on set-screws (24) and (25), to facilitate setting microswitches (22) and (23).

(3) Larger cams with graduated periphery to facilitate setting.

(4) Transfer of the timing mechanism to the top of the machine. One synchronous motor could then drive the revolution counter and cams.

(5) Photo-sensitive device to determine when the water in the jars is clear.

(6) Device for providing a continuous record of water level thus permitting a check on the periods in the cycle.

Another Division of C.S.I.R. has recently constructed a similar machine in which some of the above improvements are incorporated.

4. Acknowledgments

The work described in this paper was carried out in the Foundry Sands Laboratory at the Melbourne Technical College as part of the research programme of the Division of Industrial Chemistry.

The sincere thanks of the authors are due to the members of the Chemical Engineering Section of the Division of Industrial Chemistry who constructed the machine, and in particular to Messrs. L. R. Bull and J. Coutts who contributed a great deal to its design. They also wish to thank Messrs. R. Hastie and E. Smith of the Division of Forest Products for the photographic work, and Mr. E. J. Williams of the Section of Mathematical Statistics for the statistical analysis.

An Electrical Method of Investigating the Lubrication in a Journal Bearing

*By G. K. Tudor, B.E.**

Summary

A preliminary investigation into the lubrication of a journal bearing is described. Using a small sleeve bearing, the electrical conductance between shaft and bearing was studied by means of a cathode-ray oscillograph, the conductance variation being recorded by a moving film camera. With the particular bearing used, the investigations confirm the importance of the 'running-in' of the surfaces, the effect of shaft speed, the viscosity and temperature of the oil, and the effect of bearing load on the lubrication. Conductance traces have also been taken illustrating a further factor of considerable interest of which comparatively little is known at the present time—the rate of 'building-up' of the oil film.

1. Introduction

With lubricated metal surfaces, some indication of the extent of breakdown of the lubricant film during sliding may be obtained from a measurement of the electrical conductance across the surfaces (Bowden and Tabor 1939). Under conditions of fluid lubrication the surfaces are separated by a relatively thick unbroken film of oil which is, in itself, a very poor conductor. As a result, the conductance across the moving surfaces is extremely small. Outside the range of fluid lubrication, metallic contact, which may occur at the points of film breakdown, will be reflected in a greatly increased value of the conductance.

The electrical conductance thus gives an indication of the state of the lubrication between the surfaces. By using a cathode-ray oscillograph to record the conductance, extremely high frequency variations in the lubricant film may be followed. This method has already been used to study the lubrication between the piston-ring and the cylinder-wall of a running engine (Courtney-Pratt and Tudor 1946; Poppinga 1940).

2. Electrical Measurements

The method used for measuring the electrical conductance is a modification of that used by Courtney-Pratt and Tudor (1946) and is essentially potentiometric. A "swamping" resistance was placed in series with the resistance between the shaft and bearing and the potential difference across the oil film amplified by a direct coupled amplifier. The output of the amplifier deflected the spot of the cathode-ray tube and was recorded by means of a camera with a continuously moving film. Timing marks on the film every 1/100 sec. were produced by arranging a small neon glow tube in the field of the camera and exciting it from the 50-cycle mains. A strobotron tube

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631-P-1 was also flashed once each revolution. Insulated current and potential leads were passed through holes drilled in the housing end-covers and soldered to the bearing bush. Electrical contact to the rotating shaft was obtained by use of a mercury trough in which revolved a thin copper disc attached to the shaft. At high speeds the arrangement proved unsatisfactory, however, and four laminated copper brushes were then used, two brushes in parallel for both current and potential leads. Subsidiary measurements showed that no significant spurious effects were produced by the use of these laminated copper brushes. When calibrating, compensation was arranged for the resistance of the current leads.

With the exception of bias batteries the direct coupled amplifier was AC operated. The amplifier proved stable in operation and no trouble was experienced with drift which is common in such amplifiers. Two push-pull stages were used (6SH7 followed by EL3N6) with a high impedance input, a gain of approximately 2000 flat from zero to 80 kc.

3. Conductance Measurements in the Study of Lubricant Film Breakdown

Since the conductance measurements were carried out by a potentiometric method it was necessary to determine the form of the current-voltage relation for the junction between the surfaces. A

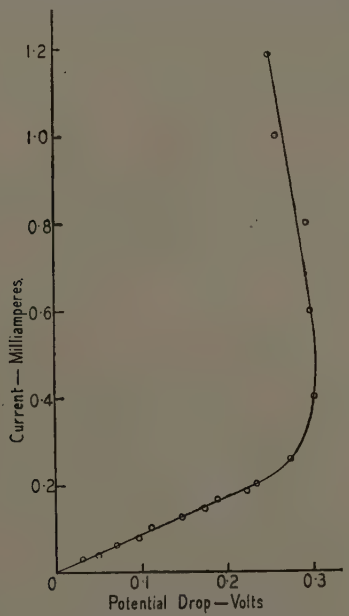

Fig. 1.—Current-voltage relationship for contact between journal and bearing.

number of current-voltage curves were plotted under different conditions of load and temperature. A typical curve is shown in Fig. 1. For low values of voltage across the oil film the current-voltage

curve is linear, indicating constant film conductance. Within this range the resistance of the film is, therefore, ohmic. As the potential across the film is increased, however, a point is reached where the proportional relationship no longer holds, the current increasing more rapidly than if this were the case. The value of the voltage corresponding to this breakdown of the linear relationship is affected by the conditions under which the bearing is running. Except under the more adverse conditions, which have not been studied in this preliminary work, the breakdown occurs at voltages above approximately 0·2 volt. It is interesting to note that the general form of the curve is similar to that previously obtained for the film between the piston-ring and the cylinder-wall of an engine (Courtney-Pratt and Tudor 1946). The behaviour is thought to be due to the electrical rupture or breakdown of the oil film due to the voltage across the film.

Subsidiary experiments carried out during the investigation point to the fact that this physical rupture of the oil film actually takes place. Conductance traces were taken with a low value of the applied voltage. After applying, even for short periods, a higher voltage (beyond the safe range as shown in Fig. 1) it was noticed that, on reducing the applied voltage to its former low value and repeating the conductance traces, the conductance between the surfaces had increased greatly. Similar experiments using a lower value of the applied voltage, indicated that an increase in the applied voltage to 0·2 volt, did not cause any alteration in the conductance traces. For this reason, in all conductance measurements described in this report, the potential drop across the junction between bearing and shaft has been limited to a value below 0·2 volt.

4. Bearing Machine

A sketch of the bearing housing used may be seen in Fig. 2. A bronze bush ($1\frac{3}{4}$ in. diam. by $1\frac{3}{4}$ in.) was mounted in the housing, and insulated from the latter by a sleeve of bakelized canvas. The bearing shaft was initially supported at each end in self-aligning ball races. It was found however that it was impossible to eliminate throwing

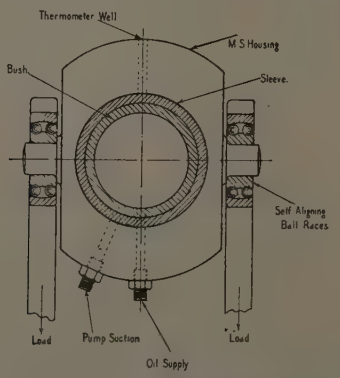

FIG. 2.—Diagrammatic illustration of test bearing and housing.

of the shaft due to eccentricity in the ball races available. White metal bearings were finally fitted and the shaft bedded-in by scraping. An oil groove extended over three-quarters of the width of the bush. The oil was fed under pressure to the bush from a small gear pump. A closed system was used for the oil supply, the circuit including a two gallon oil reservoir and "Streamline" filter. A pressure gauge and temperature well enabled observation of the pressure and temperature of the oil supplied to the bearing. Care was taken to avoid aeration of the oil. The oil pipes were led to the bearing through flexible connections. The shaft was Vee belt driven from an electric motor. A lever mechanism was used to apply load to the bearing through two side links, the load being transmitted to trunnions on the bearing housing through two self-aligning ball races.

5. Results

With the exception of work described in the section on the effect of oil viscosity, a "Californian Pale" Oil G.913 was used throughout the investigation. The oil is a straight mineral oil having a viscosity of 35·4 centistokes at 20°C.

The normal procedure was to record the resistance trace over 8-10 consecutive revolutions of the shaft. A typical trace was then selected for reproduction showing the resistance variation over a complete revolution. These typical traces may be seen in Plate 6. The interval between arrowheads at the foot of each trace represents one revolution, the arrowheads signifying the position of the flash of the strobotron lamp mentioned previously. Small variations in the time scale between traces have been neglected. The extremely rapid variation in resistance between shaft and bearing may be seen. When comparing traces to determine the effect of some change in the operating conditions the most important factor is the proportion of the trace at "zero" and "infinite" resistance. The trace with the greater portion at "zero" resistance is regarded as indicating a deterioration in the quality of lubrication between the surfaces.

In some cases when a higher camera speed than normal was used, it was not practicable to reproduce the trace over a complete revolution; in these cases a section of the trace was selected, as nearly as possible representative of the resistance variation over a revolution. The values of bearing pressure quoted in the following sections are based on the projected area of the bearing. All temperatures given are feed oil temperatures.

(i) *Time of running.*—In the early part of the investigation a study of the current-voltage relationship for the junction between shaft and bearing was made by measuring average values of the resistance under various conditions. It was noticed that a gradual increase in the resistance occurred with time after the shaft was set in motion. The improvement continued for a considerable period after each start. If the bearing was disturbed at any stage the building-up process had to be repeated. It was decided to determine if a similar effect could be observed from a comparison of a series of resistance traces taken at intervals after starting. Plate 6 shows the results of a run taken at a speed of 190 r.p.m. with a bearing pressure of 460 lb. per sq. in. Each section reproduced represents approximately

one revolution of the shaft and all traces commence at approximately the same relative position of shaft and bearing. Sections (a), (b), (c) and (d) were taken five minutes, twenty minutes, forty minutes and two and one quarter hours respectively after starting and show the gradual increase in resistance across the surfaces. No explanation is offered for this phenomena which may possibly be instrumental. It will be seen also from the traces that the regions of lowest resistance in all four films generally correspond to the same portion of the revolution. It was decided that, in order to make comparisons between the resistance traces taken under different conditions of load, speed, temperature, etc. the traces should be recorded after equal periods of running from standstill. This arbitrary procedure was observed throughout the whole of the investigation, except in the case of work done on running-in, which was carried out before the effect was noticed.

(ii) *The effect of the running-in of the surfaces.*—The procedure adopted during the experiments on the effect of running-in fortunately ensured that the traces were recorded after approximately equal intervals of running time from the stationary position. Between each trace the bearing was given a further period of running with gradual increase in the load as the load carrying capacity of the bearing increased. A set of typical traces taken during the running-in is shown in Plate 7. In the first, second, and third films approximately one-sixth of a revolution has been reproduced. The remaining film represents approximately one third of a revolution.

All films were taken under the same conditions of speed and temperature and with a bearing pressure of 210 lb. per sq. in. The first trace, taken after a running period of approximately one hour with a pressure of 210 lb. per sq. in., would seem to indicate considerable breakdown of the lubricant film between shaft and bearing. The second film taken after a further 10 hours running at the same load shows a marked improvement in the lubrication. Traces (c) and (d) were taken after further running periods of ten hours at 330 lb. per sq. in. pressure and twenty hours at 460 lb. per sq. in. pressure, and show a further improvement in the lubrication. In the latter cases, before recording the resistance trace, the load was reduced to give a bearing pressure of 210 lb. per sq. in. in order that all four traces should be obtained under the same conditions of load.

(iii) *Reproducibility.*—It was necessary to examine the reproducibility of the method before comparisons could be made of traces taken under different operating conditions. The initial running-in of the surfaces was continued until traces taken under duplicated conditions showed reasonable similarity. Also traces at standard loads etc. were taken at intervals throughout the investigation to detect any change which might occur owing to the continued running of the bearing.

Some idea of the degree of reproducibility attained during this investigation may be obtained from a study of Plates 8 and 9. Each trace has been taken with a bearing pressure of 530 lb. per sq. in. and at a speed of 190 r.p.m. It has already been mentioned that the

normal procedure was to record the resistance trace over approximately 8-10 consecutive revolutions of the shaft. From this a typical trace for the resistance over one revolution was selected. Plate 8 shows the resistance trace over three consecutive revolutions of the shaft. It will be seen that the three traces are almost identical, with the regions of higher resistance occurring at the same relative positions during the revolution. Study of the original films showed that even isolated high resistance "flashes" occupying a very small fraction of a second in time are reproduced. In Plate 9 the first trace of Plate 8 has been repeated and is compared with a trace taken approximately two hours later and with a further trace taken one week previously. Here the degree of divergence is somewhat greater than in the case of the consecutive revolutions. Possibly this divergence could be attributed to small differences in operating conditions, such as temperature changes in the oil supply and at the bearing surface itself over which no rigid control has been maintained. However, such a divergence was not regarded as sufficient to influence the trends being observed in the present investigation and brought about by considerable changes in the operating conditions.

(iv) *Load variations.*—To illustrate the effect of load variation on the lubrication, a number of traces were taken after equal intervals of running time from standstill with bearing loads of 210, 380, 460 and 530 lb./sq. in. In all cases the higher load produced a progressive deterioration in the quality of lubrication.

(v) *Variation with speed.*—The study of the lubrication with variation of shaft speed proved to be of considerable interest.

A series of three shaft speeds was obtained by alteration of the pulley ratio between motor and bearing shafts. At each speed a number of traces were taken at standard loads after equal intervals of time. Plate 10 (a)–(c) show traces taken at a load of 530 lb. per sq. in. and at speeds of 190, 335 and 550 revolutions per minute. Films in all cases were recorded after 20 minutes running. The improvement in the lubrication with increase in speed can be readily seen.

During the experiments it was noticed that the lubricant film appeared to build up much more rapidly at higher shaft speeds. It was therefore decided to record the resistance trace during starting. The procedure adopted for these tests was very arbitrary but proved sufficiently satisfactory to allow a demonstration of the rate of build-up of the film at different speeds. A load of 380 lb. per sq. in. was used in all cases throughout the investigation. In order to avoid starting the loaded bearing from standstill, the machine was started under only the dead weight of the lower arm, after which the load was applied. To obtain conditions comparable with starting under load for the starting tests, the power for the motor was cut off with the bearing running under load. The shaft was allowed to slow down to as low a speed as possible without stopping, at which instant the power was again turned on, the camera being started at the same instant.

The results of one series of starting tests are reproduced in Plates 11 and 12. Nominal shaft speeds of 335 r.p.m. and 550 r.p.m. respectively were used. The figures show the resistance trace for the first, second, third, sixth, and ninth revolutions after restoring the power to the motor. During the early part of the first revolution the speed of the shaft is lower than the nominal value owing to the limited acceleration of the motor but the correct speed has been attained in both cases by the beginning of the second revolution. The more rapid rate of building-up of the oil film at the higher shaft speed will be observed. Similar traces taken at a lower speed of 190 r.p.m. showed a slower rate of building-up.

(vi) *Viscosity and temperature.*—As already mentioned for all traces reproduced in this report, a " Californian Pale " oil G.913 has been used. However, to determine the effect of viscosity traces were taken using a heavier oil (Californian Pale G.917). This oil has a viscosity of 264 centistokes at 20°C. compared with 35·4 centistokes for G.913 at the same temperature. The results indicated a considerable improvement in lubrication with the heavier oil. Experiments were also carried out with varying temperatures of the oil supplied to the bearing. Increases in this temperature caused a marked deterioration in the resistance indicating less favourable conditions of lubrication.

6. Conclusion

The paper describes a preliminary investigation into conditions affecting the lubrication in a journal bearing by recording the electrical conductance between shaft and bearing.

Conductance traces have been taken illustrating the effect of the running-in of the bearing surfaces, the improvement in lubrication during the initial running-in being reflected in higher resistance. Improvement in the lubrication has also been observed with increase in the viscosity of the oil supplied to the bearing, and with higher shaft speeds. Increase both in the load applied to the bearing and in the temperature of the oil supply caused marked deterioration in the lubrication.

One of the most interesting results is the illustration by means of conductance traces of the apparent continued improvement in the lubrication with time of running after each start. In some cases a gradual improvement has taken place over a period of several hours. This effect has also been observed by recording average values for the resistance between shaft and bearing. Also the rate of build up is greatly influenced by the speed of rotation of the shaft, the process being far more rapid at higher shaft speeds.

Resistance traces are also given indicating the degree of reproducibility obtained by the method of analysis. In many cases high or low resistance " flashes " of the order of 1/1000 second in duration are reproduced at corresponding parts of conductance traces for consecutive revolutions of the shaft. In general when operating conditions are simulated, the trace bears the same general form as previously, except for some alteration in isolated short duration resistance " flashes." This is presumably due to slight variations in the operating conditions.

No effort has been made to correlate conductance traces with the value of the ZN/P function. For this purpose it would be necessary to maintain much more rigid control of the conditions of operation between shaft and bearing.

The fact that the trends observed with variation of factors such as speed and load, together with viscosity and temperature of the oil supplied to the bearing, are as expected from theoretical considerations, again indicates the applicability of the method to the study of lubrication problems.

7. Acknowledgments

The author is indebted to Mr. H. F. Eggington for his assistance with the experimental work and for the preparation of the plates for reproduction; also to Mr. A. E. Ferguson and Mr. R. W. Muncey for the design and construction of the electrical apparatus.

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The Effect of the Viscosity of the Medium on Polarographic Diffusion Currents

*By H. A. McKenzie, M.Sc.**

Summary

The influence of the viscosity of the medium on polarographic diffusion currents is examined, and it is shown that changes in viscosity produced by substances in true solution have considerable influence, while viscosity changes due to the presence of lyophilic colloids have little influence in the absence of secondary effects. These observations are compared with similar phenomena associated with ion conductance, and their significance in polarographic practice is discussed.

1. Introduction

The precision and reliability of polarographic analyses are largely dependent on the control of those factors which affect the diffusion current. Until recently little attention had been given to the influence of the viscosity of the supporting electrolyte.

The work of Vitek (1935), Perrachio and Meloche (1938), Shaikind (1940), Zan'ko and Manusova (1940), and Gentry (1946) demonstrated that the diffusion current in mixed solvents, such as dioxane-water, alcohol-water, and ethylene-glycol-water, was related to the viscosity. Brasher and Jones (1946) and Collenberg and Scholander (1946) showed that the diffusion currents for metal ions are inversely proportional to the square root of the viscosity of the supporting electrolyte.

The effect of the viscosity of lyophilic colloids on the diffusion current has not hitherto been examined. The author (McKenzie 1946; Lewis and McKenzie 1947) has shown that the diffusion current of oxygen is not appreciably affected by changes in the viscosity of the medium produced by the presence of the colloid pectin, but is affected by changes in viscosity due to sugars. In an attempt to investigate this phenomenon further, a study was made of the relation between the diffusion current of several metal ions and organic molecules in various media, in which the viscosity was varied by the addition of a solute (sucrose) or lyophilic colloids.

2. Experimental

Determinations of the diffusion current were made in the following systems:

Lead: 0·001M in 1M potassium chloride.

Cadmium: 0·001M in 1M potassium chloride.

Zinc: 0·001M in 1M potassium chloride.

Maleic acid: 0·001M in buffer pH 1, containing sulphuric acid (0·28M) and sodium acetate (0·1M).

Orange II: 0·001M in buffer pH 4, containing potassium hydrogen phthalate (0·05M).

* An officer of the Division of Food Preservation and Transport.

Ascorbic acid: 0·0002M in buffer pH 4·6, containing oxalic acid (0·01M), potassium hydrogen phthalate (0·025M), and sodium hydroxide (0·025M), as recommended by Gillam (1945). A concentration of 0·0002M was used, since in concentrations of the order of 0·001M peculiar maxima were observed which could not be suppressed by the usual agents.

It was planned to vary the viscosity in each system by the addition of sucrose, pectin, gelatin, or methyl cellulose. However, in some systems secondary effects occurred. Thus gelatin caused precipitation in the Orange II and ascorbic acid media; methyl cellulose and gelatin, in the maleic acid system, caused a decrease in the slope of the curve and a shift in the half-wave potential; and methyl cellulose caused the cadmium step to become so distorted that an accurate measure of the diffusion current could not be obtained.

In the lead, cadmium, and zinc solutions, 0·01 per cent. gelatin was present in every case as a maximum suppressor. This addition was not necessary in the other systems as no maxima occurred.

The diffusion current measurements were made on a manual polarograph similar to that described by Kolthoff and Lingane (1941). The rate of flow of mercury from the capillary, determined in 0·1M KCl, was 1·47 mg./sec. The drop time was determined in each supporting electrolyte medium under the applied potential at which the diffusion current was measured, and was in the neighbourhood of 4 seconds. The diffusion currents were corrected for the residual currents at the same applied potentials. Oxygen was removed by the passage of electrolytic hydrogen except in the case of the anodic wave for ascorbic acid where its removal was not necessary.

The viscosities of the solutions were measured with an Ostwald type viscometer, the viscosity of water at 25°C. being taken as unity.

3. Results

The results of the experiments are shown in Table 1. From the diffusion currents observed the diffusion current constants have been calculated from the Ilkovic equation (see below) in order to eliminate the effect of changes in the drop time.

4. Discussion

The Ilkovic equation for the diffusion current obtained with the dropping mercury electrode is:

$$i_d = KnD^{\frac{1}{2}} Cm^{\frac{2}{3}} t^{\frac{1}{6}},$$

where K is a constant,
n, the number of electrons involved in the reduction,
D, the diffusion coefficient,
C, the concentration,
m, the rate of flow of mercury from the capillary,
t, the drop time.

TABLE 1.—RELATION OF DIFFUSION CURRENT CONSTANT TO VISCOSITY

Other Substances Added	Concentration. g./100 ml.	Diffusion Current Constant (I)	Relative Viscosity (η)	($I\eta^{\frac{1}{2}}$)
(*a*) Lead (0·001M) in potassium chloride (1M)	..	4·00	1·05	4·10
Sucrose	22·8	2·89	2·01	4·10
„	43·0	1·93	4·86	4·26
Gelatin	1·0	3·50	1·63	4·47
„	3·0	2·68	4·43	5·64
Pectin	0·3	3·60	1·94	5·01
„	0·6	3·16	3·52	5·93
Methyl cellulose	0·2	3·90	1·90	5·38
„ „	0·4	3·78	3·2	6·76
(*b*) Cadmium (0·001M) in potassium chloride (1M)	..	3·62	1·05	3·71
Sucrose	22·8	2·68	2·01	3·80
„	43·0	1·81	4·86	3·99
Gelatin	1·0	3·32	1·63	4·24
„	3·0	3·04	4·43	6·40
Pectin	0·3	3·43	1·94	4·78
„	0·6	3·38	3·52	6·34
(*c*) Zinc (0·001M) in potassium chloride (1M)	..	3·46	1·05	3·55
Sucrose	22·8	2·62	2·01	3·72
„	43·0	1·81	4·86	3·99
Gelatin	1·0	3·11	1·63	3·97
„	3·0	2·67	4·43	5·62
Pectin	0·3	3·15	1·94	4·39
„	0·6	3·07	3·52	5·76
Methyl cellulose	0·2	3·28	1·90	4·52
„ „	0·4	3·22	3·2	5·76
(*d*) Orange II (0·001M) in buffer pH 4	..	3·70	1·03	3·76
Sucrose	22·8	2·59	2·04	3·70
„	43·0	1·73	4·96	3·85
Pectin	0·3	3·56	1·94	4·96
„	0·6	3·43	3·52	6·44
Methyl cellulose	0·2	3·31	1·90	4·56
„ „	0·4	3·17	3·2	5·67
(*e*) Ascorbic acid (0·0002M) in buffer pH 4·6	..	3·20	1·03	3·25
Sucrose	22·8	2·27	2·02	3·23
„	43·0	1·53	4·89	3·38
Pectin	0·3	3·20	1·94	4·46
„	0·6	3·00	3·52	5·63
Methyl cellulose	0·2	3·09	1·90	4·26
„ „	0·4	3·00	3·2	5·37
(*f*) Maleic acid (0·001M) in buffer pH 1·1	..	3·78	1·06	3·89
Sucrose	22·8	2·77	2·14	4·05
„	43·0	2·00	4·95	4·45
Gelatin	1·0	3·51	1·63	4·48
„	3·0	3·33	4·43	7·01
Pectin	0·3	3·68	2·55	5·88
„	0·6	3·64	3·86	7·15
Methyl cellulose	0·2	3·62	1·90	4·99
„ „	0·4	3·47	3·2	6·21

This equation may be re-written:

$$I = K' D^{\frac{1}{2}},$$

where I is the diffusion current constant ($i_d/Cm^{\frac{2}{3}} t^{\frac{1}{6}}$) and K' is constant.

The Stokes-Einstein equation for a diffusing particle can be written:

$$D\eta = K''$$

where D is the diffusion coefficient, η the viscosity, and K'' a constant.

Combining the two equations then,

$$I\eta^{\frac{1}{2}} = K''',$$

where K''' is a constant.

Calculations from the results of Brasher and Jones (1946) indicate that the latter relation is valid within a few per cent., when the viscosity is changed by varying the concentration of the supporting electrolyte. This agreement can be regarded as satisfactory since the Stokes-Einstein equation does not take into account the influence of ionic strength and is strictly valid only when the moving particle is spherical and much larger than the molecules of the solvent medium. In the tabulated results above the product $I\eta^{\frac{1}{2}}$ has been calculated.

It will be seen that, when the viscosity of the medium is varied by the addition of sucrose, $I\eta^{\frac{1}{2}}$ is approximately constant over the range of viscosities covered. This is in accord with the observations of other workers (Brasher and Jones 1946; Collenberg and Scholander 1946) who varied the viscosity by the addition of different true solutes, but when the viscosity is varied by the addition of lyophilic colloids, $I\eta^{\frac{1}{2}}$ is no longer constant. Expressing this in another way, viscosity changes produced by sucrose affect the diffusion currents considerably, but viscosity changes produced by the colloids have in most cases little effect. Where there is a significant effect on diffusion current, e.g. the effect of gelatin on the diffusion currents of lead and zinc, it can generally be explained in terms of complex formation. Kolthoff and Lingane (1941) have attributed the decrease in the diffusion current of lead in the presence of gelatin to complex formation. The smaller change in diffusion current produced by pectin may be due to a similar effect, since Baker and Goodwin (1939) have observed complex formation between these metals and pectin.

It appears, therefore, that viscous substances in true solution considerably influence diffusion currents while, in the absence of secondary reactions, lyophilic colloids have little effect. This conclusion is in accord with the fact that dilute gels have practically no influence on the rate of diffusion of substances in true solution, and with observations on the effects of viscous substances in true and colloidal solution on ion conductances.

Arrhenius (1885, 1916) first drew attention to the phenomenon that the electrical conductivity of salt solutions is hardly affected when a gelatin sol changes into a gel, although the viscosity is greatly increased, and he postulated that in both the gelatin sol and the gel the ions move at the same speed through interstices between the gelatin particles. Green (1908) wrote as follows:—"Arrhenius' . . . . work indicates that in some cases at least the

two fluidities (ionic and physical) are not identical; indeed in such cases they may be compared on the one hand to the passage of water through the interstices of a fine sponge and, on the other to the sponge itself being forced to flow through the tube in such a way that no circumferential slipping takes place." This picture is in accord with modern views on the structure of gels. On the other hand, Walden and others (Dědek and Dykyj 1936) have shown that, in systems in which colloids are not present, ion conductivity is considerably affected by the viscosity of the solvent and, in many systems, the product of the equivalent conductance at infinite dilution and the viscosity of the solvent is a constant (Walden's Rule).

It is considered that the observations reported have important implications regarding polarographic practice. For instance, it is apparent that particular attention should be paid to the viscosity of the supporting electrolyte medium when applying the polarographic method to technical and biological materials.

The Nernst equation $D = \frac{RT}{ZF^2}\lambda^\circ$ has frequently been used in polarography to determine the approximate diffusion coefficient of ions. Its use can only be justified when the viscosity of the supporting electrolyte is close to unity.

It is generally assumed that the limiting current of a neutral molecule is independent of the concentration of supporting electrolyte since the limiting current is solely a diffusion current (Kolthoff and Lingane 1941; Giguère and Lauzier 1945). This assumption will be true only in the case of a supporting electrolyte in which the viscosity does not change appreciably with concentration, e.g. potassium chloride.

5. Acknowledgments

Grateful acknowledgment is made to Mr. J. F. Kefford for much helpful discussion during the course of this work, and to Miss H. Smith for technical assistance.

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Note on Night-time Phenomena in the F_2-Region at Brisbane

By G. de V. Gipps, B.Sc., D. I. Gipps, B.Sc.,* and H. R. Venton, B.Sc.**

Summary

(h',f) records made on the multifrequency ionospheric recorder at Indooroopilly reveal certain departures from normal F_2 region formation at night. These phenomena are classified in three groups and possible ionosphere configurations to produce these phenomena are discussed.

1. Introduction

In the pulse method of measuring ionospheric characteristics a short radio pulse is emitted by the transmitting system which, after vertical reflection in the ionosphere overhead is picked up by a receiving system and may be displayed on a cathode-ray tube. The equipment in use at Brisbane is an automatic recorder of the type designed by the Radio Research Board (1). The screen of the cathode-ray tube is photographed on moving 35 mm. film while the frequency of the transmitter is subject to a continuous sweep. This results in a graphical representation of the ionosphere, plotting virtual height for the various layers against frequency. Such a record is made during the first 2½ minutes of each quarter hour.

Under normal conditions the Earth's magnetic field results in the single transmitted wave being resolved in the ionosphere into two separate elliptically polarized waves, called respectively the ordinary ray (o-ray) and the extraordinary ray (x-ray) by analogy with optical double refraction in crystals. These waves travel in different manners in the ionosphere and as a result can often be distinguished at the receiving system if short pulses are used. The characteristic result of this "magneto-ionic" splitting is shown in Plate 13 (D). Two separate traces can be seen as the critical frequency is approached, the trace showing the lower critical frequency being the ordinary ray. (The critical frequency of an ionospheric region is the highest frequency of radio waves reflected by the region at vertical incidence.) McNicol (2) has calculated from the strength of the Earth's magnetic field at the point of reflection above Brisbane (estimated from the strength of the magnetic field at the ground), the difference in critical frequency between the o- and the x-rays. His results are quoted in the following table:

f^x in Mc/s.	$f^x - f^o$ in Mc/s.		
	h = 100 km.	h = 200 km.	h = 300 km.
2	0·95	0·89	0·84
4	0·81	0·76	0·73
6	0·77	0·74	0·70
8	0·75	0·72	0·69
10	0·75	0·71	0·68

* A member of the staff of the Physics Department of the University of Queensland, working in co-operation with the Council's Radio Research Board.

With the aid of this table it is possible to interpret the more complex records which are to be discussed.

Occasionally at Brisbane, each of the components of the simple "magneto-ionic" splitting appear themselves to have split in height and critical frequency as shown in Plates 13 (A–C) and 14 (A–D). Further, on frequent occasions a phenomenon which is termed "diffuseness" has appeared (Plate 14 (D)) where instead of a well-defined height of reflection there is a broad range of heights from which echoes have been received. Diffuseness may arise from scattering by small irregularities (in ionization density) in the F_2–region, however, it seems probable that the additional splitting may be due to normal-incidence reflections from larger irregularities not quite overhead. (Unfortunately at Brisbane only single-point records are available. The interpretation of these records would be much simplified by investigating the ionosphere at a number of points separated horizontally by distances of 20 to 100 km.)

2. Diffuse Reflections

It has been found that records showing diffuseness have decreased in number and that the average amount of diffuseness present has also

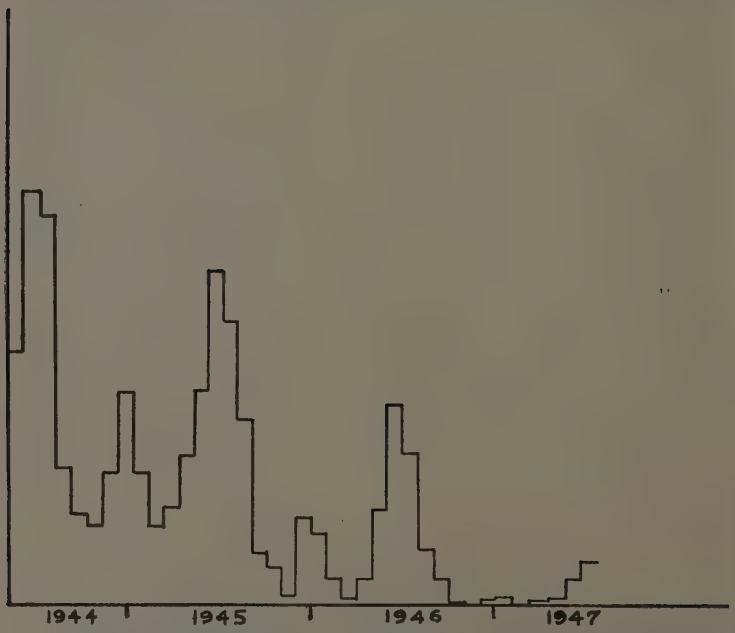


FIG. 1.—Histogram of mean monthly value of diffuseness from May 1944 to June 1947 obtained by adding the hourly index figures for each hour of the month.

decreased as shown in Fig. 1 since the Brisbane records of it started in May 1944. (It has probably decreased from the year of sunspot

minimum.) In the years of maximum occurrence it was noted that diffuseness was greater in winter, less in summer and least on the summer side of the equinoxes. Its occurrence was centred at about 0130 hours local time.

When diffuseness is prevalent it does not occur in the same degree each night; but a night in which little diffuseness appears may occur in the midst of a series of nights when much diffuseness is present. However, diffuseness forms and disappears gradually during any particular night, and any record showing much diffuseness is almost always preceded and succeeded by records showing less diffuseness.

On occasions it has been noted that diffuseness first appears in the records in the form of "clouds" corresponding to frequencies above the critical frequencies of the *o*– and *x*–rays in the F_2 region, and in successive records the initial frequencies of the "clouds" move down to below the critical frequencies. Finally, the diffused *o*–ray overlaps the diffused *x*–ray to give one diffuse echo with a sharp low frequency edge to the *o*-ray penetration (Plate 15). This type of diffuseness has been reported very frequently in polar regions (3). The lower edge of the "cloud" can be quite sharp as in Plate 16, Fig. 1. These phenomena can be accounted for if one assumes that the ionospheric irregularities responsible for the diffuseness are initially located above the level of maximum ionization density in the F_2 region. In this way one can readily understand why the diffuse echo is not visible until the critical frequency has been passed. Again, the trace ends abruptly without the usual upward sweep. This would suggest that the diffuse reflections occur within a region characterized by gross irregularities of ionization rather than by a consistent ionization gradient. For a number of small reflecting clouds, all of approximately the same ionization density, would show no rise in effective height with increasing frequency owing to the negligible size of individual clouds. The *Es* region which is probably a shallow region of clouds of high ionization density also shows little change of height with frequency.

As the irregular clouds of ions gradually descend they produce scattering from lower heights and frequencies. Once they reach the minimum height of F_2 reflection the trace can assume the diffuse appearance characteristic of equatorial regions (3); the inner edge of the *o*–ray trace is no longer well-defined but is obscured by diffuse reflections, over a wide range of heights, appearing well below the critical frequency. Sometimes, however, the region responsible for diffuse echoes is sufficiently separated in a horizontal direction from the zenithal F_2 reflecting region, to give a parallel diffuse trace above, and extending beyond, a fairly sharp F_2 trace (Plate 16, Fig. 2).

Since diffuseness prevents the detection of additional splitting, records showing such splitting are mostly confined to the period just after night conditions in the ionosphere have started, and occasionally just before the pre-sunrise minimum. In the present winter (1947) however, when diffuseness is rare, records showing additional splitting have been obtained at all hours of the night.

3. Complex Splitting

Two types of splitting are recognized, the first beginning with the appearance of a fork on the upward sweep of the *o*– and *x*–ray traces. This may later develop to show apparent reflecting "regions" at

slightly different heights and with different critical frequencies. Or the difference in critical frequency between the arms of the fork may increase while the virtual height remains apparently the same. If the difference in virtual heights is less than about 10 km. the two traces would not be resolved, and the thickening of the true trace would scarcely be noticed. In the majority of cases when the split echo shows diffuseness only near its critical frequencies, as time proceeds each individual trace of the fork begins to lose its sharpness below its critical frequency. As diffuseness develops still further each trace merges into the other arms of the fork until a broad diffuse " cloud " of the type characteristic of polar regions is produced (Plate 14) (3). This is to be expected if the diffuse reflection comes from a large region of irregular ionization which gradually descends and enters both the overhead F_2 region and any closely neighbouring irregularity.

In Plate 16, Fig. 2, the F_2 trace shows a fork of 0·4 Mc/s. as well as indicating an additional reflecting " region." This could be explained by assuming the existence of a large irregularity almost overhead in the F_2 region, and a patch of small irregularities further to one side (corresponding to a greater " effective height ").

In the second type of splitting which for convenience we call height-splitting, there appear to be two layers having the same critical frequency but differing in virtual height—the difference increasing with time. Either the second " layer " (which is comparable in strength to the true F_2 echo) increases in virtual height till the difference in heights is, say, 130 km., and then it disappears, as in Plate 13, or more than one spurious layer forms and a " thick " (i.e. diffuse) echo is gradually built up. As the top of the F_2 trace at night is not always uniform (owing to the varying sensitivity of the recorder amongst other things) the growth of diffuseness along the flat part of a height-split echo is not so obvious.

Since no echo can be received from a region above the F_2 until the critical frequency of the normal F_2 region is passed, the most probable explanation is that the other echo must be received from an oblique direction, thus giving a greater virtual height. See ray III, in Fig. 2.

Fig. 2 shows a possible formation of the ionosphere giving both types of splitting. Ray I is the normal ray. Ray II strikes the lower surface of the ionosphere at approximately the same distance as ray I, but the gradient is less and the maximum ionization is less owing to a vertical expansion of the region in this area; thus the trace from ray II will have the same virtual height but a smaller critical frequency than the trace from ray I. Ray III traverses a greater distance before it reaches the minimum height of reflection, but then strikes the same gradient and maximum ionization as ray I; thus the trace would be above and parallel to the trace from ray I. The essential difference between the two types of splitting is that the gradient and maximum ionization of the reflecting points are sensibly the same for the height split echo as for the zenithal F_2 echo and noticeably different in a forked echo.

During the time when a height split is developing the critical frequency and virtual height of the normal overhead F_2 region vary very little, e.g. in Plate 13 $h'F_2$ drops from 300 km. to 290 km. in thirty

minutes and then rises 20 km. while $f^{o}F_{2}$ remains about 6·6 Mc/s. It is indeed not unreasonable to expect that a steady horizontal movement of an irregularity in ionization would be associated with a generally steady condition of the ionosphere.

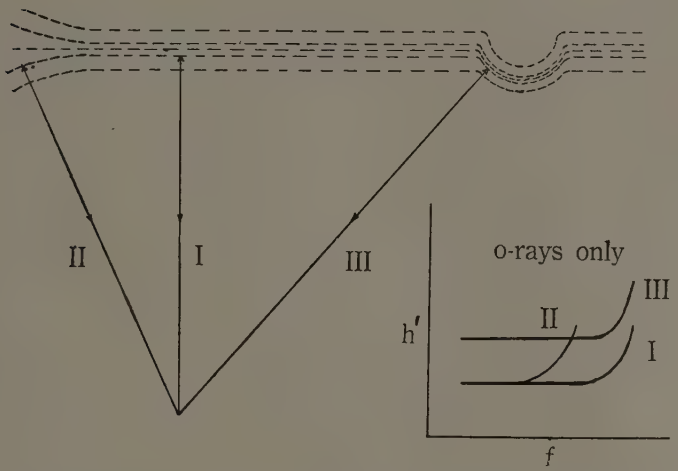


FIG. 2.—A possible conformation of the ionosphere which would result in three traces being recorded. Ray I being the path of the usual echo, ray II producing a frequency split echo, and ray III a height split echo.

When height splitting is present it would not be expected that the difference in virtual heights of the split components in the second reflections would be the same, or even twice, those in the first reflections.

In Plate 13 the second echo rises from 30 km. above the F_2 echo to 130 km. above the F_2 echo in thirty minutes. In terms of a wave (or some such irregularity) travelling along the under-surface of a flat ionosphere (the curvature may be neglected), this would give a velocity of the order of 300 km. per hour.

Several serious difficulties are met in the interpretation of height-split echoes. The records are frequently spoiled by the lower edges of the traces being hard to determine, i.e. the difference in virtual heights is very doubtful. The maximum life observed for an irregularity with steady motion has been less than forty-five minutes. The phenomenon often appears on only one record. Thus any echo at a height of about 100 km. greater than $h'F_2$ would probably be interpreted as an $F + E$ reflection if any *Es* is present. As the recorder is active for one-sixth of the total time, it is not possible to tell if an irregularity which shows only on one quarter-hour record is approaching or receding. The direction of motion and therefore the true velocity cannot be measured from one point.

There are some interesting points connected with these records:

(*a*) On rare occasions the virtual height of the second echo does not remain a constant height above the F_2 echo throughout the frequency sweep (Plate 16, Fig. 3). This perhaps indicates local differences in layer thickness. If the ionization gradient (along the path of the incident ray) is greater in one part of the region than another, the virtual height for the same frequency may be either greater or less in the latter part, but as the frequency increases the virtual height of the echo from the latter part will increase more rapidly than that from the former.

(*b*) As the spurious component of a height-split echo fades in the early morning before sunrise, the lower frequencies fade first.

(*c*) The difference in critical frequency between the various arms of the forked *o*–ray can extend to as much as 1·0 Mc/s. If the difference is 0·7–0·8 Mc/s. the upward sweep interpreted as the normal *o*–ray coincides with, or at least overlaps, the abnormal fork on the *x*–ray upward sweep, giving the appearance of a *z*–ray (Plate 17, Fig. 1). No case of a true *z*-ray has ever been recorded at Brisbane.

(*d*) Both forms of splitting may occur in what has been a "quiet" night, i.e. the lower surface of the ionosphere is very flat, as shown by reflections up to, say, the fifteenth multiple. (These echoes can be recognized by their greater slope, and are received on the second sweep of the time-base after the original transmitter pulse, the time difference for this being equivalent to 3,000 km. in virtual height. The order of the multiple can thus be found from the virtual height of the first reflection.) It is also possible to have diffuseness after the penetrations simultaneously with these high multiple reflections. Thus the diffuse reflections must be returned from a greater height than the normal F_2 height of reflection which is so well defined that the reflection coefficient from it is very high.

(*e*) Sometimes an F_2 region at night shows a stratification which develops into a fork. This might be a large irregularity directly above the main F_2 layer (as seen from the recorder) which moves laterally and downwards until it is at the height of the latter (Plate 5, Fig. 2).

These records suggest that the F_2 region may be affected by very localized disturbances such that two neighbouring portions separated by, say, 20 km. may have different ionization densities and gradients, thus giving echoes of different critical frequencies and virtual heights. These small disturbances (which are possibly corpuscular in nature) may also be the primary cause of diffuseness. The effects observed in Brisbane are similar to, but more prolonged than, those described by H. W. Wells, J. M. Watts and D. E. George (Carnegie Institute of Washington). Since the above article was written our attention has been drawn to a Canadian publication in which a similar interpretation of the phenomenon of complex splitting is put forward (4).

4. Acknowledgments

This information has been obtained from records of the ionospheric recorder operated by the Physics Department of the University of Queensland in conjunction with the Radio Research Board of C.S.I.R. and is published with the permission of the latter body. The authors wish to thank Professor H. C. Webster for his many helpful suggestions.

5. References

(1) Wood, H. B.—Design of an automatic variable frequency radio transmitter with automatically tuned receiver. Coun. Sci. Ind. Res. (Aust.), Bull. No. 110, p. 19 (1937).

(2) McNicol, R. W. E.—Some aspects of ionosphere investigation (1944). (Confidential.)

(3) Minutes of I.R.P.C. Conference, Washington, April–May, 1944, Section 4, Committee A, Item 3.

(4) Meek, J. H., and Davies, F. T.—Observers instruction book for Canadian ionospheric stations. Canadian Radio Wave Propagation Committee (1946).

Note on the Treatment of Textile Materials with Methyl Silicon Amine to give Improved Resistance to the Penetration of Moisture

*By R. J. Meakins, B.Sc., Ph.D., D.I.C.**

Summary

Cotton and woollen fabrics treated with a solution of methyl silicon amine in benzene showed greatly improved resistance to capillary water absorption.

The methyl silicon amine used in this treatment was obtained by the action of liquid ammonia on a commercial sample of the corresponding chloride mixture.†

The cotton and woollen materials for test were cleaned by washing with soap and distilled water, dried and immersed in a 1 per cent. solution of methyl silicon amine in dry benzene. The samples were then dried in a current of air and heated for two hours at 105° C. The cotton samples thus treated showed resistance to wetting by a stream of running water impinging on the surface, an untreated sample being saturated almost immediately under these conditions. In a similar test with the woollen material, both the treated samples and the controls resisted wetting, probably owing to the high apparent contact angle associated with the structure of the fabric.‡

A quantitative indication of the improved resistance to moisture resulting from the treatment with methyl silicon amine was obtained from a simple capillary water absorption test. Strips of equal size were cut from samples of the treated materials and controls, rolled loosely, and inserted into short lengths of glass tubing of suitable diameter. Each such unit was weighed and then placed in a small dish of distilled water so that the lower end of the roll of material was just below the water level. The percentage increases in weight are shown in the accompanying table.

TABLE 1.—CAPILLARY WATER ABSORPTION OF COTTON AND WOOLLEN TEXTILE MATERIALS TREATED WITH METHYL SILICON AMINE

Material	Weight of Dry Sample (g.)	Percentage Increase in Weight After Periods of Exposure of—		
		2 Hours	22 Hours	94 Hours
(*a*) Cotton—				
Untreated	0·36	150	170	290
Treated	0·38	5	10	20
(*b*) Wool—				
Untreated	1·16	70	160	230
Treated	1·20	2	14	17

From these results it is evident that the use of methyl silicon amine for reducing the water-affinity of cotton and woollen textile materials shows considerable promise. In similar tests, ethyl silicon amine proved less effective, possibly due to inefficient adsorption under these conditions of treatment.

* On Officer of the Division of Industrial Chemistry, seconded to the Division of Electrotechnology.

† International General Electric Co.—Improvements in or relating to methods of rendering materials water-repellent. Aust. Pat. No. 21568/45.

‡ Cassie, A. B. D., and Baxter, S. (1944).—Wettability of porous surfaces. *Trans. Faraday Soc.* 40: 546.

NOTES

Imperial Agricultural Bureaux

The name "Imperial Agricultural Bureaux" has been changed to "Commonwealth Agricultural Bureaux" as from January 1, 1948. The change has been made because the Executive Council of the Bureaux feels that the use of the word "Commonwealth" rather than "Imperial" is more in keeping with modern trends.

C.S.I.R. Information Service

The C.S.I.R. Information Service is now located at the Head Office of the Council and its address is 314 Albert Street, East Melbourne, C.2, Victoria.

Reviews

"Five Hundred Varieties of Herbage and Fodder Plants", edited by M. Hall.

(Bulletin 39 of the Commonwealth Bureau of Pastures and Field Crops, 1948, pp. 300. Copies obtainable from the Liaison Officer, Commonwealth Agricultural Bureaux, 314 Albert Street, East Melbourne, C.2. Price 18s. 9d.)

This Bulletin is issued in the form of a descriptive catalogue of recognized species and varieties of fodder plants. Under each variety details are given of its origin, the authority responsible for its development, its characteristics, adaptation, use and certification, together with notes on the market for seed. Species are arranged alphabetically and varieties are grouped according to the country of origin or use.

Australian material is covered better than that of many other countries. For example, fifteen varieties of feed oats and eighteen varieties of maize useful for fodder are listed. Recognized varieties of Australian pasture plants, such as the seven commercial or semi-commercial strains of subterranean clover, are included.

The Bulletin is of particular interest to persons concerned with the introduction and breeding of pasture plants and forage crops. The availability of useful varieties or genetic characters from local and overseas sources can be readily determined. The Bulletin will also be a useful reference document for agriculturalists and seedsmen who give advice on the choice of varieties for specific purposes. As might be expected in a first edition of a work of this kind a coverage of all species in all countries has not been achieved, nor are the descriptions of uniform degree of detail in all instances.

A valuable feature of the publication is the index giving references to information on all varieties of pasture and forage plants appearing in Volumes 1–17 of Herbage Abstracts. This index provides access to fuller information on any variety in which the reader is interested.

"Phenothiazine 1942-46."

(A Review and Bibliography, by J. Tweedle Edwards and the Imperial Bureau of Agricultural Parasitology (Helminthology), 1947. Imperial Agricultural Bureau Joint Publication No. 12. Obtainable from the Liaison Officer, Commonwealth Agricultural Bureaux, 314 Albert Street, East Melbourne, E.2. Price 5s.)

Edwards reviews the literature on phenothiazine in veterinary medicine for 1942-46, and deals with pharmacology, toxicology and the clinical application of the drug. The drug behaves differently in different species of animals so that it is essential to consider toxicity separately for the various species. Cattle and horses are the most susceptible of all domestic animals but the reasons for this are not at all certain. The difference between cattle and sheep is surprising, but recent studies in New Zealand by Clare (*Aust. Vet. J.* 23: 340, 1947) suggest a reason for this difference. In cattle usually, and in sheep when a large dose is given, the conversion of phenothiazine sulphoxide to phenothiazone in the liver is not complete, so that the sulphoxide reaches the systemic circulation. Clare, Whitten and Filmer (*Aust. Vet. J.* 23: 344, 1947) showed that the sulphoxide may enter the aqueous humor of the eye and thereby produce a state of photosensitivity to sunlight leading in some cases to a severe keratitis.

The effect of the obviously different metabolism of phenothiazine on toxic effects in cattle, apart from causing keratitis, has not been determined.

Edwards notes that it has been suggested that constipation is conducive to phenothiazine poisoning, particularly in horses, but that is not supported by experimental or authoritative clinical evidence. It has also been suggested that the toxicity hazard is less if the dose is divided over several days, instead of being given at one time. Edwards points out that the daily divided dose was exactly what had been used in those human cases where toxic effects developed.

In the section on clinical application the technique of administration, form of drug, preparation of patient, dose, effect of climate and farming practice, hazards, and evaluation of results are discussed. The individual animals are then considered and there are tables to indicate the degrees of efficiency against the various species of nematodes and summaries of the literature on methods of administration and toxicity.

There are brief sections on phenothiazine therapy in other animals, on the action of phenothiazine in non-helminthic diseases of domestic animals, and the use of phenothiazine in helminthiasis in man.

A bibliography for the years 1942-46, prepared by the Commonwealth Bureau of Agricultural Parasitology (Helminthology), follows and is set down under the respective years.

—H. McL. G.

Recent Publications of the Council

Since the last issue of this *Journal,* the following publications of the Council have been issued:

Bulletin No. 223.—"Report of Marine Borer Survey in New Guinea Waters," by A. W. Shillinglaw, B.Sc., Dip.For., and D. D. Moore, B.Sc., A.S.T.C.

The survey described in this Bulletin was carried out in 1945 to determine the nature and extent of damage to harbour installations by marine borers in New Guinea waters, and to find whether any timbers (either Australian or New Guinea species) were sufficiently resistant to marine borer attack to warrant their use in Service structures, and whether any protective measures were practicable to extend the life of timber used in harbour installations.

The results of the investigation were published in mimeographed form by the Scientific Liaison and Information Bureau as Report T.S.S.5 in September 1945, and the present Bulletin has been issued to give wider circulation to the report, as the subject matter is of considerable significance in the maintenance of wharf and harbour installations in Australia and the Pacific area in particular.

Bulletin No. 231.—"Mint Weed, *Salvia reflexa* Hornem. Present Distribution and Status in Australia," by R. Roe, B.Sc. (Agric.), and N. H. Shaw, B.Agr.Sc.

A comprehensive survey of the distribution and status of mint weed was made in 1945 as a basis for renewed investigation of the weed, previous work having been interrupted during the war.

The survey showed that mint weed does not invade vigorously growing and carefully grazed pastures. Invasion of a natural pasture only occurs where the stand has been reduced in vigour by mismanagement, or where openings have been made along roads or tracks or, for example, round watering troughs. Experiments to determine means of controlling the weed have not been very successful. Chemical methods on their own do not offer a practicable solution and the natural regeneration of grazing land when spelled from stocking is too slow. The use of vigorously competing pasture species has been unsuccessful because of difficulties in establishing these species on the heavy-textured self-mulching soils favoured by the weed.

The geographical distribution of mint weed in southern Queensland has been indicated on a map.

Bulletin No. 234.—"Mineral Deficiency in Plants on the Soils of the Ninety-Mile Plain in South Australia. 2. Effect of Zinc, Copper, and Phosphate on Subterranean Clover and Lucerne Grown on Laffer Sand, near Keith," by D. S. Riceman, M.Sc.

This Bulletin describes the effects, observed over a period of three years, of addition of zinc sulphate and different quantities of copper sulphate and superphosphate to a mixed pasture sown without a cover crop on recently cleared Laffer sand.

There was a marked contrast in the behaviour of subterranean clover, lucerne, and Phalaris in response to the various manurial treatments. The highest yields of subterranean clover were obtained each year where the dressing of superphosphate, which was applied at seeding, was not a heavy one. Yields of lucerne increased as the rate of application of superphosphate at seeding was increased up to 8 cwt. per acre, but only where copper had been applied in addition.

The yield of Phalaris was enhanced by addition of superphosphate, but zinc and copper had little or no effect in the experiments.

The results confirm the contention expressed in an earlier paper that the Laffer sand and probably the extensive areas of other types of poor, sandy soils in the Ninety-Mile Plain will prove highly productive when given suitable dressings of superphosphate, to which the required trace elements have been added. Treatment of Laffer sand is economic, and only superphosphate must be applied annually.

Forthcoming Publications of the Council

At the present time, the following future publications of the Council are in the press:

Bulletin No. 232.—"Guide to the Medicinal and Poisonous Plants of Queensland," by L. J. Webb, B.Sc.

Bulletin No. 233.—"A Soil Survey of the Hundred of Seddon and Part of the Hundred of MacGillivray, Kangaroo Island, South Australia, including also Portions of the Hundreds of Cassini and Duncan," by K. H. Northcote, B.Agr.Sc., and B. M. Tucker, B.Sc.

Bulletin No. 236.—"Observations on the Plant Communities at "Bundemar," Trangie District, New South Wales, in Relation to *Chortoicetes terminifera* (Walk.) and *Austroicetes cruciata* (Sauss.)," by L. R. Clark, M.Sc.

Bulletin No. 237.—"Heating in Stored Wheat. I. Respiration of Dry Grain, Insect Respiration, and Temperature and Moisture Effects," by Joan Milthorpe, B.Sc., and R. N. Robertson, B.Sc., Ph.D. "II. Heat Production, Heat Conductivity, and Temperature Rise in Grain in the Presence and Absence of Insects," by R. N. Robertson, B.Sc., Ph.D. "III. Two Years' Temperature Records of Dry Grain in a Concrete Silo," by R. N. Robertson, B.Sc., Ph.D., and Joan Milthorpe, B.Sc.

Bulletin No. 238.—"Non-parasitic Disorders of Australian Apple Fruits," by W. M. Carne.

Bulletin No. 239.—"Foundry Sand Resources of New South Wales," by H. A. Stephens, M.Sc., and H. F. Whitworth, M.Sc.

Bulletin No. 240.—"Studies on Dietary and Other Factors Affecting the Serum-Calcium Levels of Sheep," by M. C. Franklin, M.Sc., Ph.D., R. L. Reid, and I. L. Johnstone, B.V.Sc.

Bulletin No. 241.—"An Australian Phytochemical Survey. I. Alkaloids and Hydrocyanic Acid in Queensland Plants," by L. J. Webb, B.Sc.

Bulletin No. 242.—"The Age, Rate of Growth, and General Life-history of the Australian Pilchard (*Sardinops neopilchardus*) in New South Wales Waters," by M. Blackburn, M.Sc.

Bulletin No. 243.—"A Soil, Land-use, and Erosion Survey of Parts of the Counties of Moira and Delatite, Victoria, including the Parishes of Pine Lodge, Dookie, Devenish, Currawa, Stewarton, Caniambo, Gowangardie, Upotipotpon, Goomalibee, Tamleugh, Shadforth, Wills, Warrenbayne, Boho, Moglonemby, and Balmattum," by R. G. Downes, M.Agr.Sc.

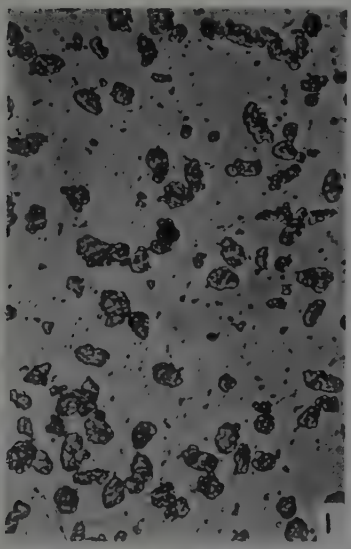
Bulletin No. 244.—"Observations on Wheat in a Victorian Bulk Depot," by F. Wilson.

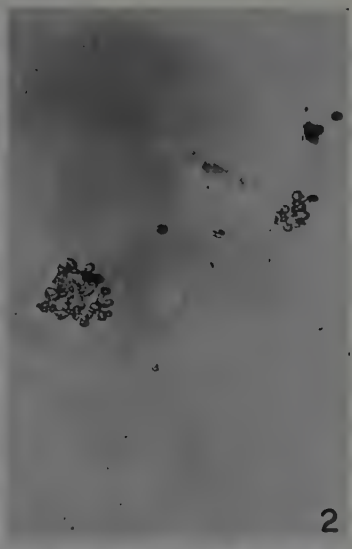
Bulletin No. 245.—"Observations on the Behaviour of Swarm Hoppers of the Australian Plague Locust *Chortoicetes terminifera* (Walker)," by L. R. Clark, M.Sc.

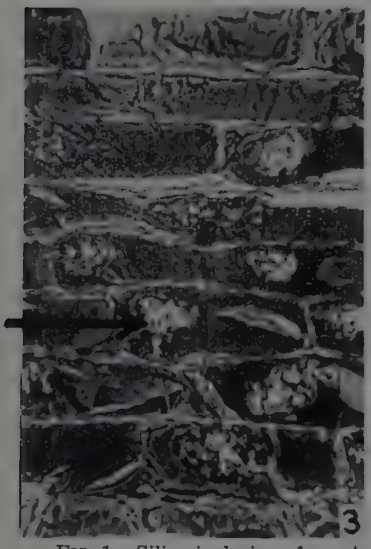
"Handbook of Australian Pelagic Tunicates," by Harold Thompson, M.A., D.Sc.

PLATE 1

Siliceous Inclusions in Wood in Relation to Marine Borer Resistance.
(See page 190.)







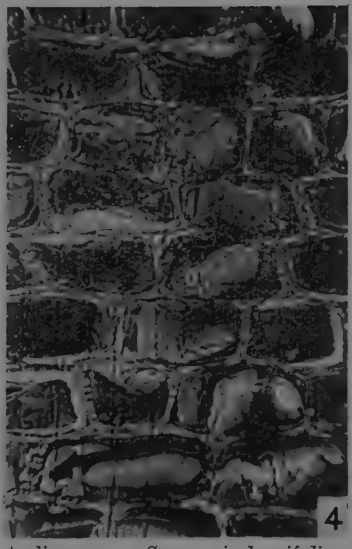


FIG. 1.—Silica inclusions from Australian-grown *Syncarpia laurifolia* Ten. isolated by wet combustion with sulphuric and nitric acids. (X220)

FIG. 2.—Clusters of small inclusions from Hawaiian-grown *Syncarpia laurifolia* Ten. isolated by wet combustion. (X220)

FIG. 3.—Typical ray tissue of Australian-grown *Syncarpia laurifolia* Ten. showing large siliceous inclusions (indicated by the arrow) imbedded in resinous matter. (X460)

FIG. 4.—Typical ray tissue of Hawaiian-grown *Syncarpia laurifolia* Ten. showing sparsely distributed smaller inclusions imbedded in resinous matter. (X460)

NOTE.—The lenticular light areas in Figs. 3 and 4 are cracks in the resin of the ray cells.

PLATE 2

Siliceous Inclusions in Wood in Relation to Marine Borer Resistance.
(See page 190.)

FIG. 1.—*Tristania suaveolens* Sm. Ray tissue showing siliceous inclusions. (X450)

FIG. 2.—*Xanthostemon pachyspermus* F.v.M. Ray tissue showing siliceous inclusions. (X450)

FIG. 3.—*Anisoptera polyandra* Bl. Ray tissue showing siliceous inclusions. (X450)

FIG. 4.—*Viticipremna novae-pomeraniae* (Warb.) H.J. Lam. Showing siliceous inclusions in the septate wood fibres. (X450)

PLATE 3

Machine for Determining Clay Substance. (See page 197.)

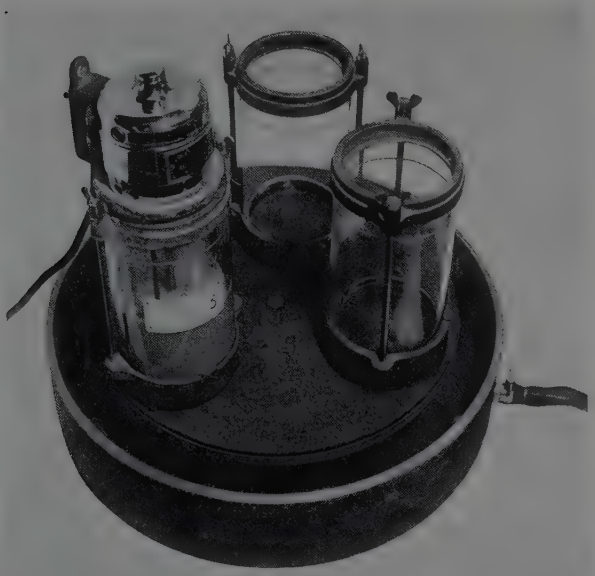


FIG. 1.—Sand washing jars and electric stirrer.

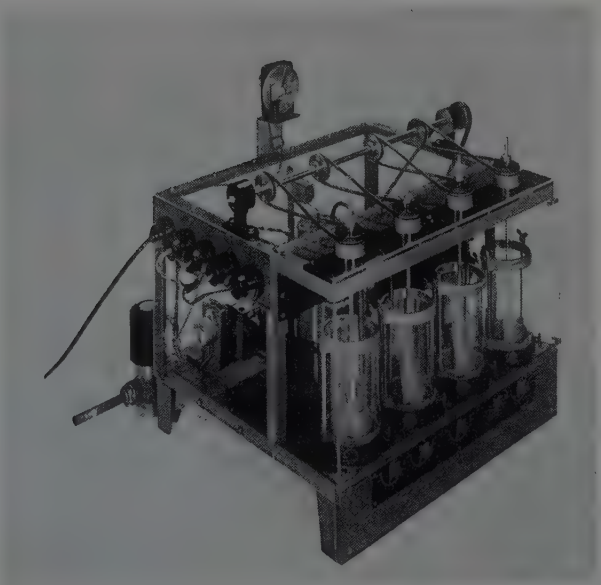


FIG. 2.—General view of machine (perspex cover attached).

PLATE 4

Machine for Determining Clay Substance. (See page 197.)

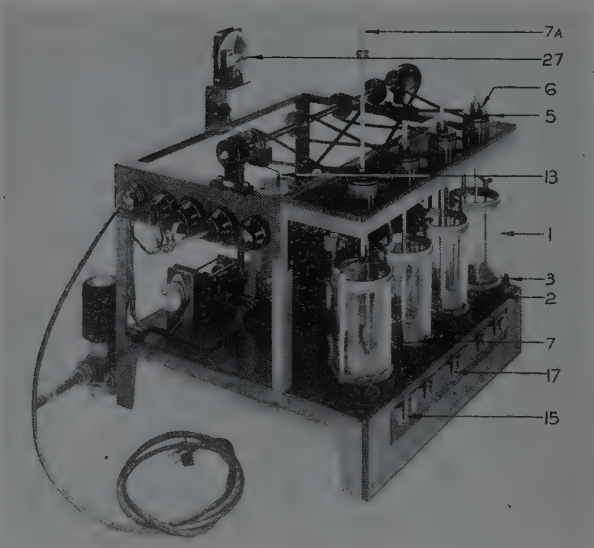


FIG. 1.—Left-hand side view (perspex cover removed). (Includes Nos. 1-3, 5-7A, 13, 15, 17, and 27.)

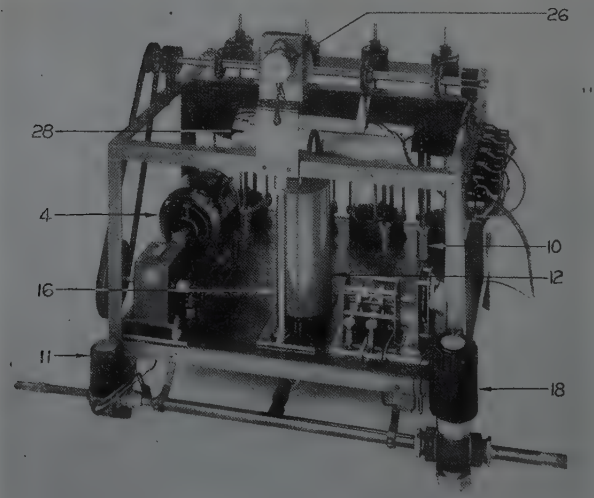


FIG. 2.—Rear view (perspex cover removed). (Includes Nos. 4, 10-12, 16, 18, 26, and 28.)

PLATE 5

Machine for Determining Clay Substance. (See page 197.)

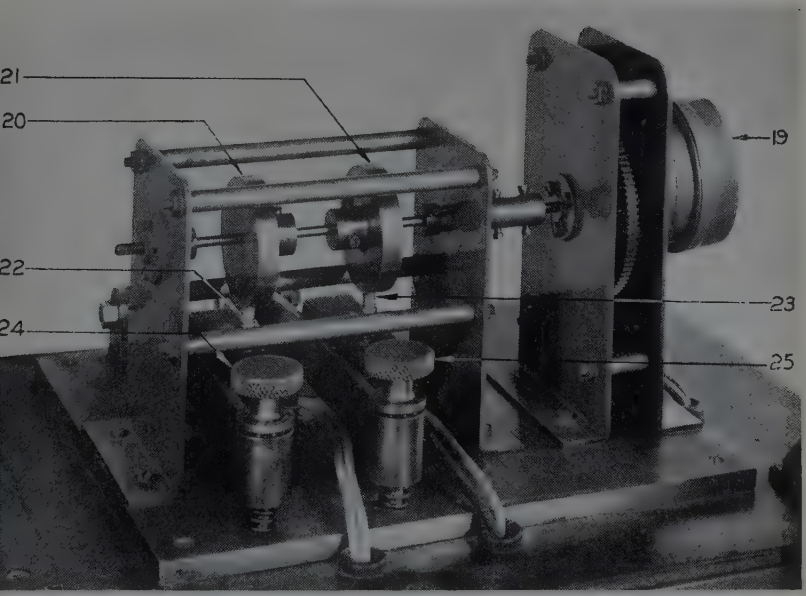


FIG. 1.—Timing mechanism. (Includes Nos. 19-25.)

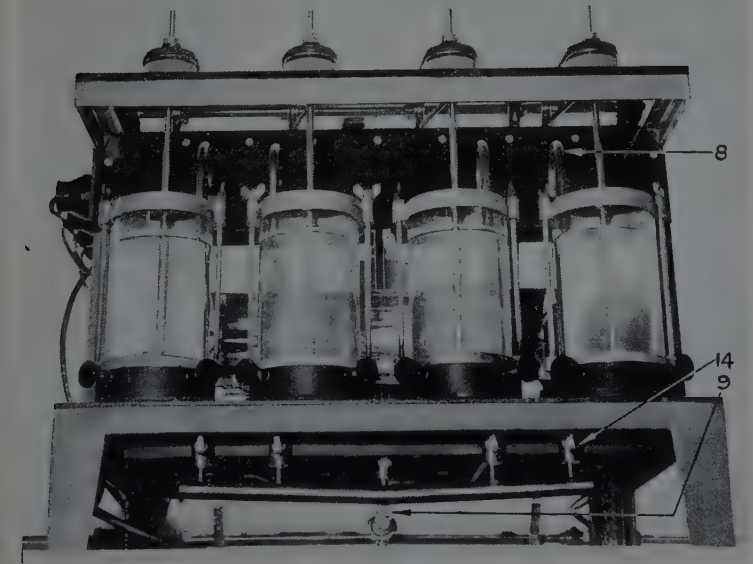


FIG. 2.—Front view of header system. (Tap control panel and perspex cover removed.) (Includes Nos. 8, 9 and 14).

PLATE 6

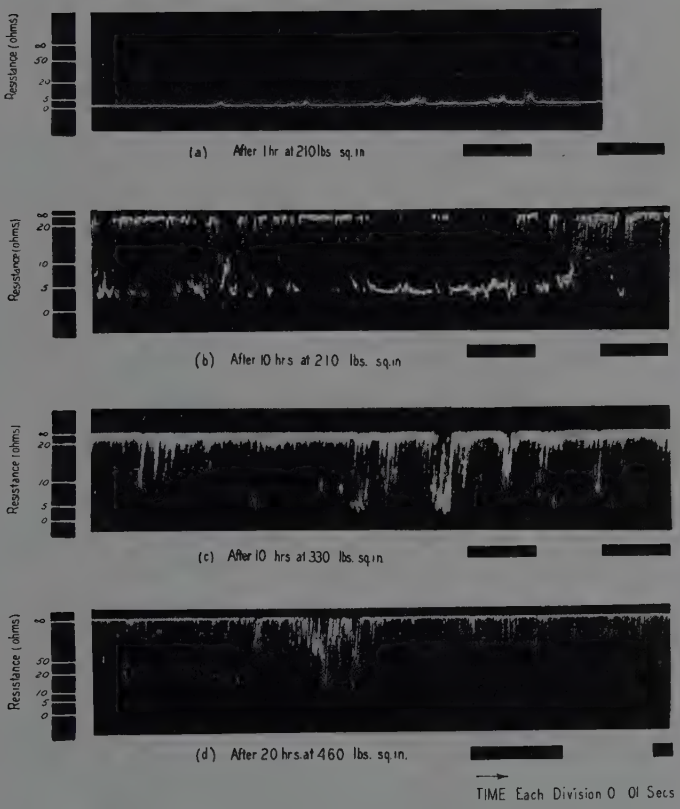
An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)

(a) 5 minutes after starting
(b) 20 minutes after starting
(c) 40 minutes after starting
(d) 2¼ hours after starting
Resistance (ohms)
TIME Each Division 0 01 Secs.

Time of running after starting. Speed 190 r.p.m., oil G.913, load 460 lb./sq. in., temperature 18°C.

PLATE 7

An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)


Resistance (ohms)
(a) After 1 hr at 210 lbs sq.in
Resistance (ohms)
(b) After 10 hrs at 210 lbs. sq.in
Resistance (ohms)
(c) After 10 hrs at 330 lbs. sq.in.
Resistance (ohms)
(d) After 20 hrs. at 460 lbs. sq.in.
TIME Each Division 0 01 Secs

Running-in. Speed 190 r.p.m., oil G.913, temperature 22°C. All films taken at 210 lb./sq. in. load.

PLATE 8

An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)

Reproducibility, showing 3 consecutive revolutions. Speed 190 r.p.m., oil G.913, load 530 lb./sq. in., temperature 20°C.

PLATE 9

An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)

Reproducibility. Load 530 lb./sq. in., oil G.913, speed 190 r.p.m., temperature 20°C.
Trace (a) is the same as first revolution, Plate 8.

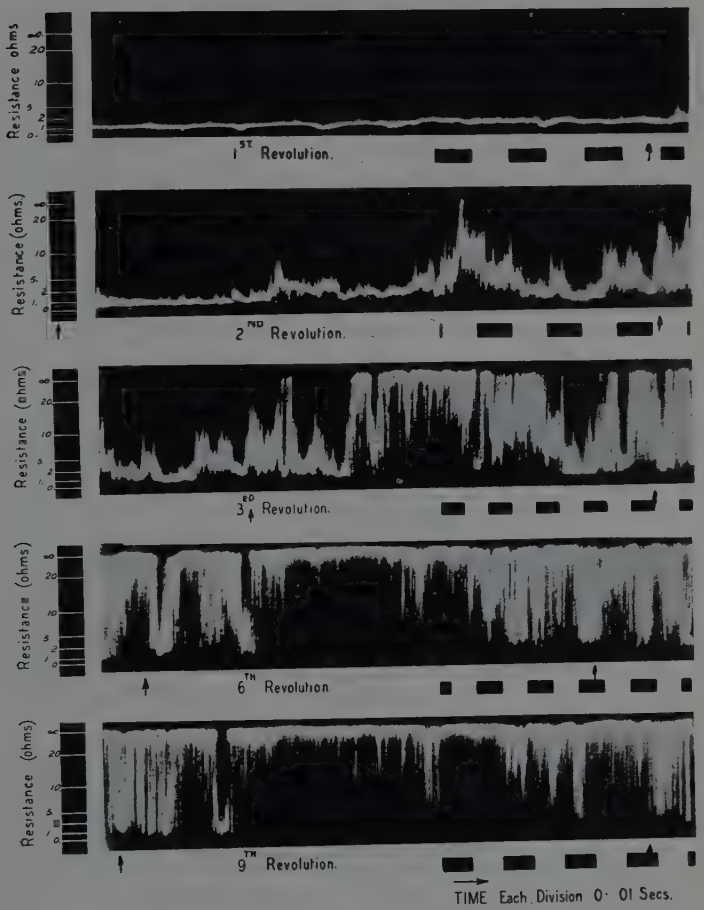
PLATE 10

An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)

Speed. Load 530 lb./sq. in., oil G.913, temperature 20°C.

PLATE 11

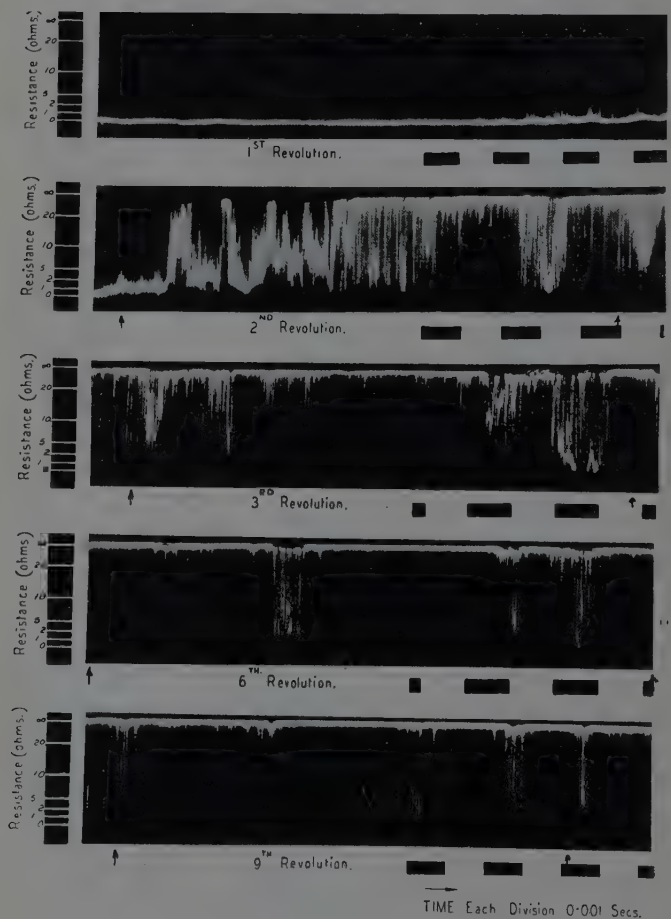
An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)



Starting test. Speed 335 r.p.m., oil G.913, load 380 lb./sq. in., temperature 19°C.

PLATE 12

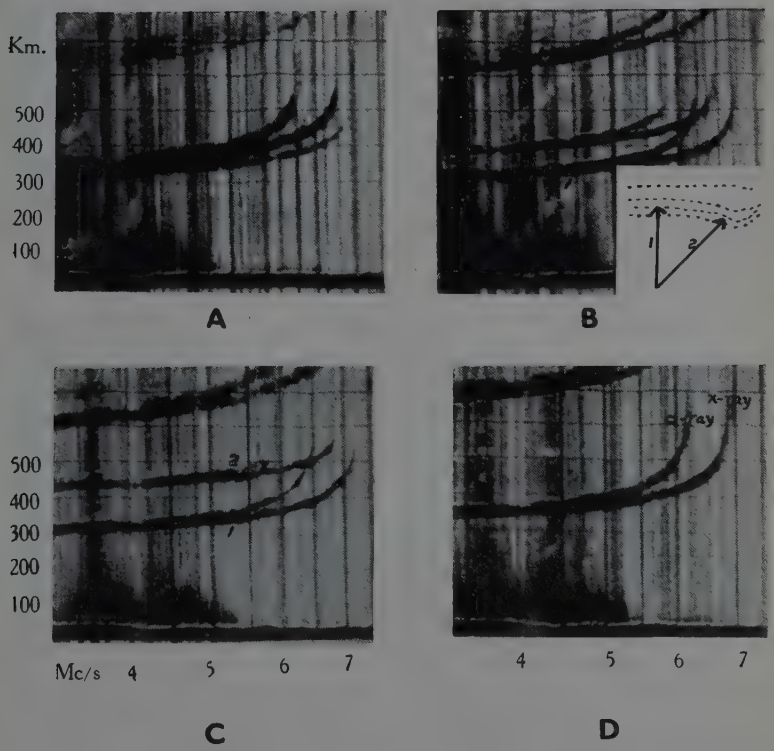
An Electrical Method of Investigating the Lubrication in a Journal Bearing. (See page 202.)



Starting test. Speed 550 r.p.m., oil G.913, load 380 lb./sq. in., temperature 22°C.

PLATE 13

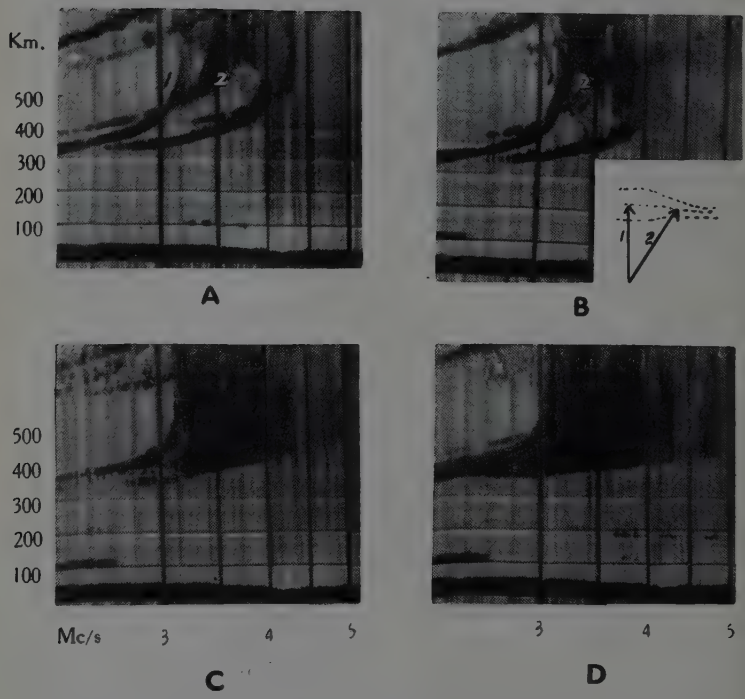
Night-time Phenomena in the F_2-Region at Brisbane. (See page 215.)



2145 hr. to 2230 hr. on 25–xi–43. The virtual height of the second echo increases from 30 km. greater than the normal F_2 echo to 130 km. greater than the latter, and then disappears. Assuming an irregularity of the same ionization gradient as the overhead F_2 region, this irregularity would have a velocity of the order of 300 km. per hour.

PLATE 14

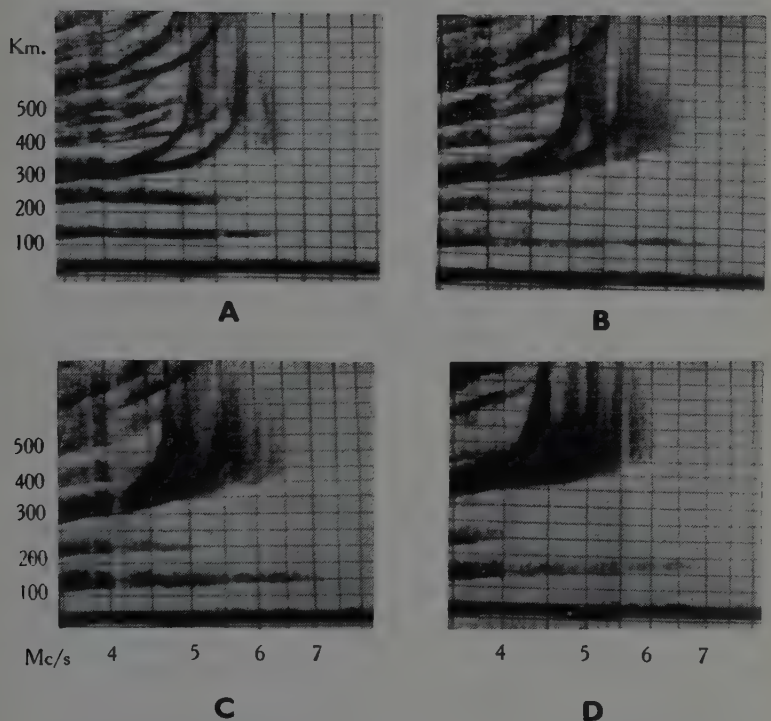
Night-time Phenomena in the F_2-Region at Brisbane. (See page 215.)



2100 hr. to 2145 hr. on 13–iii–45. After showing a fork on the penetrations the F_2 region has developed to show two "regions" with different virtual heights and different critical frequencies. Diffuseness appears on all of the penetrations, and increases till there is one diffuse echo with a sharp inside edge. This is the type of diffuse echo recorded in temperate and polar latitudes.

PLATE 15

Night-time Phenomena in the F_2-Region at Brisbane. (See page 215.)



Records from 0100 hr. to 0230 hr. on 19-v-47. Diffuseness first appears as a faint cloud after the F_2 penetration and later becomes denser as its initial frequency decreases.

PLATE 16

Night-time Phenomena in the F_2-Region at Brisbane. (See page 215.)

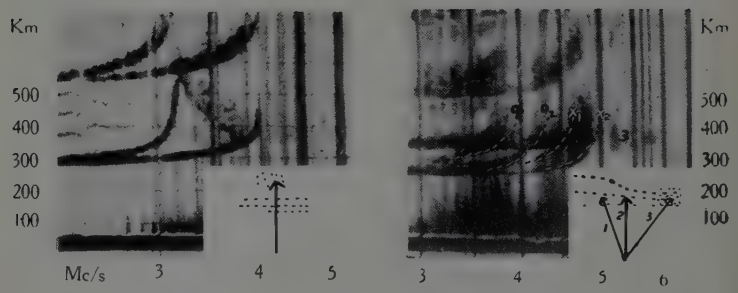


Fig. 1. (left).—0415 hr. on 3–iii–44. The lower edge of the diffuse echo after the F_2 penetration is quite sharp. The effect is scarcely visible on the x–ray.

Fig. 2. (right).—2115 hr. on 8–vi–44. There is a diffuse "layer" above and extending beyond the normal F_2 trace which also shows a fork of 0·4 Mc/s.

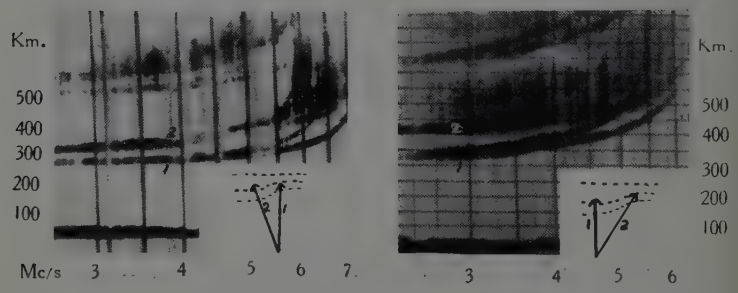


Fig. 3.—2245 hr. on 17–xii–44 and 2315 hr. on 17–vi–47. The difference in virtual heights between the two echoes increases and decreases respectively with frequency increase.

PLATE 17

Night-time Phenomena in the F_2-Region at Brisbane. (See page 215.)

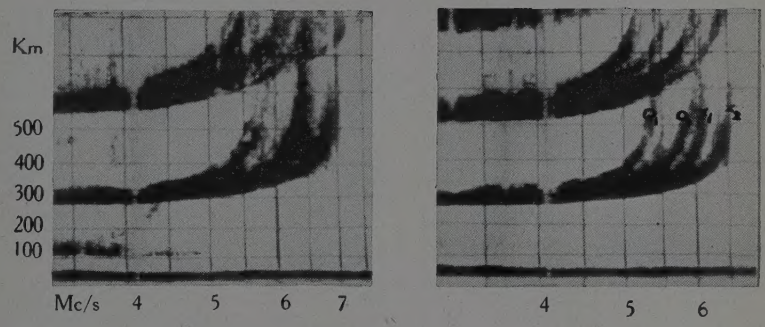


Fig. 1.—0345 hr. on 14–v–47. Three penetrations show owing to overlapping on a fork, giving the appearance of a *z*–ray. The following record at 0400 shows the difference in fork penetrations in the *o*–ray to be 0·5 Mc/s.

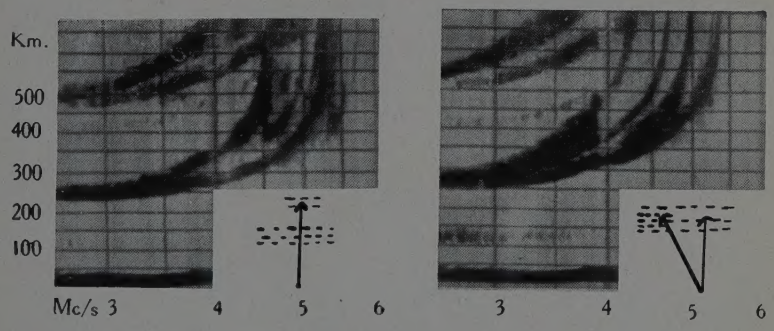


Fig. 2.—0415 hr. and 0445 hr. on 7–vi–47. A stratification of the F_2 region descends to give the appearance of a split.

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